

Historic, Archive Document

Do not assume content reflects current scientific knowledge, policies, or practices.

REPORT OF
FORTY-SIXTH ANNUAL
DATE GROWERS' INSTITUTE



EXPERIMENTAL DUSTER FOR APPLICATION OF POLLEN OR PESTICIDES

Volume 46

PUBLISHED BY THE DATE GROWERS' INSTITUTE

November 1969

REPORT OF
DATE GROWERS' INSTITUTE

Held in Coachella Valley, California
April 26, 1969

VOLUME 46 — NOVEMBER 1969

The DATE GROWERS' INSTITUTE is the official educational organization of the date industry. Its purpose is the dissemination of information on date growing, handling, marketing and research. The INSTITUTE was organized in 1924 and is supported by membership dues and sale of the annual reports of meetings. Membership is open to individuals or companies interested in the purposes of the INSTITUTE.

MEMBERSHIP AND SALE OF ANNUAL REPORT

Regular Membership — Annual dues \$5.00

Sustaining Membership — Annual dues \$10.00

Members receive the ANNUAL REPORT free. The DATE GROWERS' INSTITUTE REPORTS — Volume 1-46 may be purchased, postage free, at \$1.50 per volume or the complete set of 46 volumes at \$44.00. Direct all inquiries regarding subscriptions to the ANNUAL REPORT or purchase of back volumes to:

MRS. MARYANN GRANT, Secretary
P. O. Box 613
Indio, California 92201

**PREPARATION AND PUBLICATION
OF MANUSCRIPTS**

Publication in the DATE GROWERS' INSTITUTE ANNUAL REPORT is restricted to reports presented at a meeting of the DATE GROWERS' INSTITUTE. Authors, or the institutions which they represent, will be charged for cuts by the printer. Manuscripts must be written concisely to avoid unnecessary cost of publication. They should be carefully reviewed by two colleagues and revised before submission for publication. In the preparation of manuscripts, authors should be guided by the STYLE MANUAL FOR BIOLOGICAL JOURNALS. Second Edition, 1964. American Institute of Biological Sciences, 2000 P Street NW, Washington, D.C. 20036.

Manuscripts and inquiries concerning publication should be sent to the editor:

J. R. FURR
U. S. Date and Citrus Station
44-455 Clinton Street
Indio, California 92201

DATE INSTITUTE COMMITTEE

MRS. T. R. BROWN
T. R. BROWN
J. B. CARPENTER
H. L. CAVANAUGH
E. J. CODEKAS
J. R. FURR
E. C. JARVIS
PAUL JENKINS
B. T. LAFLIN, SR.

GEORGE LEACH
W. K. MARTIN
D. H. MITCHELL
R. W. NIXON
LEONHARDT SWINGLE
HILLMAN YOWELL
DEAN D. HALSEY, Farm Advisor,
University of California
Agricultural Extension Service

Forty-Sixth Annual DATE GROWERS' INSTITUTE

Held in
COACHELLA VALLEY

April 26, 1969

Volume 46



TABLE OF CONTENTS

<i>Chairman Morning Session</i> W. K. MARTIN <i>Manager, Date Administrative Committee, Indio, California</i>	<i>Chairman Afternoon Session</i> D. H. MITCHELL <i>Date Grower Coachella, California</i>
A CENSUS OF MALE AND FEMALE DATE PALMS IN COACHELLA VALLEY	
D. D. Halsey and B. E. Stone.....	3
LOOKING AT TEN YEARS OF DATE ACREAGE CHANGE	
William W. Cook.....	4
OBSERVATIONS ON NATURAL FRUIT DROP DURING THE DEVELOPMENT OF KHADRAWI, ZAHIDI AND DEGLET NOOR DATE FRUITS	
O. Reuveni	6
SORTING AND PROCESSING MECHANICALLY HARVESTED DATES	
C. C. Huxsoll and D. Reznik.....	8
GROWTH, DEVELOPMENT, AND SOFTENING OF THE DEGLET NOOR DATE FRUIT	
C. W. Coggins, Jr., and J. C. F. Knapp.....	11
SELECTIVE HARVEST AND FRUIT SEPARATION TRIALS WITH DEGLET NOOR DATES	
E. G. Vis, G. K. Brown, and R. M. Perkins.....	15
AN IMPROVED PESTICIDE DUSTER FOR DATE PALMS	
G. K. Brown, R. M. Perkins, and E. G. Vis.....	19
TEMPERATURE AND HEAT UNIT OCCURRENCES DURING DATE POLLINATION IN THE COACHELLA VALLEY OF CALIFORNIA	
G. K. Brown, R. M. Perkins and E. G. Vis.....	21

**EFFECT OF ELEVATION AND TIME ON AIR TEMPERATURE
DURING DATE POLLINATION**

E. G. Vis, G. K. Brown, and R. M. Perkins..... 25

**THE PERIOD OF RECEPTIVITY OF PISTILLATE FLOWERS AND OTHER FACTORS
AFFECTING SET OF DATE FRUIT**

C. L. Ream and J. R. Furr..... 29

DEVELOPING GROUND LEVEL EQUIPMENT FOR POLLINATING DATES

G. K. Brown, R. M. Perkins and E. G. Vis..... 31

EXPERIMENTS WITH AIRCRAFT METHODS FOR POLLINATING DATES

G. K. Brown and R. M. Perkins..... 36

MEMBERSHIP ROLL 1969-1970 42

COVER: Experimental Duster for Application of Pollen or Pesticides. See pages 19, 31.

CENSUS OF MALE AND FEMALE DATE PALMS IN COACHELLA VALLEY

D. D. HALSEY and B. E. STONE

University of California Agricultural Extension Service
Indio, California 92201

This census was undertaken to determine the numbers of male and female date palms in Coachella Valley where mechanical methods of pollination show promise as a substitute for hand pollination which requires a large amount of hand labor. One good male palm produces enough pollen to hand pollinate about one acre of female palms, equivalent to 48.4 palms at a spacing of 30 x 30 ft. for Deglet Noor. Mechanical methods employ up to 3 times as much pollen as hand methods and we need to learn whether a satisfactory proportion of male to female palms exists to supply the pollen that might be required if mechanical pollination becomes widely used.

Three categories of palms were counted as follows:

Farmed Female Palms: These are in commercial gardens which have been irrigated, fertilized and otherwise cared for so that they are capable of producing a crop in the 1969-70 season. They were not all pollinated for that season.

Farmed Male Palms: These are a part of or adjacent to commercial gardens now being farmed and are being looked after in much the same way as the farmed females.

Non-Farmed Male Palms: These occur in abandoned commercial gardens or gardens converted to other use such as sub-division, or are planted as ornamentals or wind-breaks. Generally they are not in condition to produce a maximum yield of pollen.

The survey method involved the use of 9 U. S. Geological Survey maps pre-

pared from aerial photographs taken in 1954. These maps are on a scale of 1 to 24,000. Each orchard is shown and can be located with respect to section lines, streets and avenues. Each date planting was assigned a serial number on the map, and a tree count was made of the orchard assigned that serial number. This makes it possible to determine the tree count at any location by reference to these maps, which will be kept on file in the Agricultural Extension Service office at Indio.

A total of 171,355 farmed female palms and 3,593 farmed males were found, Table 1. The 1,019 non-farmed males that were found could possibly be used

as pollen sources should the need arise. There are 3,644 farmed acres of dates in the valley, estimated from the tree count and an average of 48 trees per acre. The ratio of farmed males to females is 1/48.1.

Therefore, the ratio of farmed male to female palms is about the minimum required to supply pollen for hand pollination. The present farmed male population would need to be approximately doubled to supply pollen for mechanical pollination of even 50% of the present acreage of farmed female palms. A period of 8 to 12 years would be required to substantially augment the present supply of pollen.

TABLE 1. Summary of date palm census in Coachella Valley, April, 1969.

Location	Properties	Farmed female date palms	Farmed male date palms	Total farmed palms	Non-farmed male date palms
Cathedral City	15	15,432	283	15,715	4
Wyoma	2	3,861	61	3,922	
Rancho Mirage	7	3,261	65	3,326	2
La Quinta	54	33,382	743	34,125	335
Indio	122	69,631	1,360	70,991	273
Thermal Canyon	5	1,996	23	2,019	19
Valerie Jean	36	22,811	555	23,366	84
Mecca	29	12,012	286	12,298	232
Oasis	17	8,969	217	9,186	70
Totals	287	171,355	3,593	174,948	1,019

LOOKING AT TEN YEARS OF DATE ACREAGE CHANGE

WILLIAM W. COOK¹

Palm Desert, California

This paper is intended to serve both as a review and as a continuation of the report² made in 1959. Date acreage and production changes for the 10-year period 1959 through 1968 are presented. I hope that the reader will find the factual information contained herein helpful to him in making his own forecast of probable trends in the Coachella Valley date industry.

Tables 1 and 2 tell the story of the acreage changes of all dates and of major individual varieties. The total acreage change of all dates proved to be a reduction of only 3% of 1958 acreage. During the period the planting of 638 acres was recorded, and the records show removal of 209 acres. Personal knowledge of the industry and a survey indicated that many removals had not been recorded. For this reason it was necessary to balance Table 1 by inserting column 4, which makes an arbitrary estimated **net reduction of 564 acres**. The age of the palms is of considerable importance; of the present total of 4,411 acres (Table 2), 78% are 20 years of age or older, 16% are 7 to 19 years of age, and only 6% are under 7.

Plantings made during the past 10 years were concentrated in 1961, 1962 and 1963; of 638 acres planted during the period over half were planted in these 3 years. The trend in new planting has been downward since 1963 with the exception of 1966, when 61 acres were planted. The 1968 total planting was only 15 acres (10 acres Deglet Noor, 4 acres Zahidi and 1 acre Medjool).

Table 3 is a listing of date statistics published in the annual Riverside County Agricultural Crop Reports for the years 1958 through 1968, inclusive. The same data for earlier years may be found in Table 2 on page 20 of the 1959 Date Growers' Institute Report. Cull, or "waste", volume ranged from a high of 28% in 1959 to a low of 15% in 1963.

Table 4 presents the net change for the period 1958-1968 of each column shown in Table 3. Change is shown in both amount and per cent of 1958 totals. Non-bearing acres more than doubled, while total acres were reduced 6% in the 10 years. Production is down 14%, while total gross value is up 15%. Thus, fewer dates produced more gross revenue. However, the grower was squeezed economically due to higher production costs both in the field and packing house.

An attempt was made to determine the returns to the grower at the ranch for the last few years. From personal interviews and a survey made by the Extension Service, it is concluded that growers have recently received about 9c per pound for marketable dates, or

TABLE 1. Changes in acreage of date palms 1959 to 1968, inclusive

Variety	Dec. 1958 Total acres	Planted thru 1968	Removed thru 1968	Adjustment ^a	Dec. 1968 Total acres	Percentage change 1958-1968
Deglet Noor	4,008	460	-128	-573	3,767	- 6.0%
Khadrawy	166	13	- 12	37	130	- 21.7%
Zahidi	139	68	- 6	- 6	195	+ 40.3%
Medjool	55	77	- 0	0	132	+ 140.0%
Others	90	18	- 19	+ 52	141	+ 56.7%
Seedlings	88	2	- 44	0	46	- 47.7%
Total acres (all dates)	4,546	638	-209	-564	4,411	- 3.0%

^aAll figures in above table were supplied by Agricultural Commissioner of the County of Riverside with the exception of the adjusting figures shown in the fourth column above. These are estimates by the writer.

TABLE 2. Age groups by variety in the 1968 acreage of dates^a

Variety	Total acres Dec. 1968	20 years old or older	7 to 19 years old	Total bearing acres	Non-bearing acres (under 7 years)
Deglet Noor	3,767	3,060	520	3,580	187
Khadrawy	130	116	14	130	0
Zahidi	195	109	48	157	38
Medjool	132	8	105	113	19
Others	141	119	16	135	6
Seedlings	46	39	7	46	0
Total acres (all dates)	4,411	3,451	710	4,161	250
Per cent of total	100%	78%	16%	94%	6%

^aThe above figures include all plantings of date palms in the County of Riverside. All are in the Coachella Valley except for 12 acres of Deglet Noor and 8 acres of other varieties in the Palo Verde Valley.

TABLE 3. Date production and acreage for Riverside County^a

Year	Bearing acres	Non-bearing ^b acres	Total acres	Production ^c (In tons)	Valuation ^d
1958	4,426	120	4,546	22,938	\$7,004,040
1959	3,953	160	4,113	19,547	4,842,330
1960	3,944	197	4,141	24,811	7,208,390
1961	3,971	296	4,267	22,057	5,911,350
1962	4,010	297	4,307	21,219	7,025,610
1963	4,008	359	4,367	24,020	7,690,563
1964	3,795	500	4,295	19,023	6,542,439
1965	3,881	431	4,312	24,266	9,990,883
1966	3,904	413	4,317	24,196	8,623,670
1967	4,018	299	4,317	21,537	9,199,773
1968	4,161	250	4,411	19,783	8,072,427

^aAll figures are taken directly from the annual crop reports of the Riverside County Agricultural Commissioner.

^bNon-bearing acres include current year's planting for each year.

^cProduction includes marketable, substandard and cull dates.

^dValuation is gross FOB value of crop, including culls and substandard.

¹ Deceased, July 21, 1969.

² Cook, W. W. 1959. The future of the date industry in Coachella Valley. Date Growers' Inst. Rep. 36: 20-22.

an average per acre for well-operated date gardens of \$1,100 per year.

Date growers indicated an interest in a comparison of 1959 forecast figures with 1968 results. This comparison is made in Table 5. In column 1 is the prediction made, starting at line 17 on page 21, of the 1959 Date Growers' Institute Report (footnote 2). Column 2 gives the actual figures for 1968.

During the 1958-68 period the value of the dollar dropped more than expected. Due to the termination of the bracero program all desert agriculture was faced with a critical shortage of qualified farm workers. On the favorable side there was an increase in FOB value per ton from \$305 in 1958 to \$408 in 1968. Grower returns per marketable pound appear to have increased from about 7c to the indicated 9c per pound mentioned earlier. On balance, the date grower did not gain substantial encouragement. However, there was considerable planting during the middle of the 10-year period and the potential for industry growth is as good today as in 1958.

The drop in new plantings since 1966 shows weakness. Recent accumulation of carry-over inventory is a threat. Yet, history shows that the date industry has continued and even expanded in the face of problems as great as, or greater, than are those of today. All will agree that the next few years are critical. Also, it is evident that many uncertainties now existing must be resolved before a dependable and logical forecasting of the future of the date industry in Coachella Valley can be made.

TABLE 4. Net changes in acreage, production and crop value, 1958 to 1968^a

Year	Bearing acres	Non-bearing acres	Total acres	Production (In tons)	Valuation
1958	4,426	120	4,546	22,938	\$7,004,040
1968	4,161	250	4,411	19,783	8,072,427
Net change	- 265	+ 130	- 135	- 3,155	+ 1,068,387
Per cent change	- 6%	+ 108%	- 3%	- 14%	+ 15%

^aTotals for all varieties taken from corresponding columns in Table 3.

TABLE 5. Comparison of 1959 prediction of date palm acreage and yields with actual results in 1968

Acreage	Predicted situation for 1969	Actual situation, Dec. 1968
Full-bearing acres (over 10 years old)	3,500	3,781
Young bearing acres (7 to 10 years old)	200 to 300	380
Non-bearing acres (under 7 years old)	No forecast	250
Total crop	20,000 tons	19,783 tons

OBSERVATIONS ON NATURAL FRUIT DROP DURING THE DEVELOPMENT OF KHADRAWI, ZAHIDI AND DEGLET NOOR DATE FRUITS

O. REUVENI

Volcani Institute of Agricultural Research, Bet Dagan, Israel¹

INTRODUCTION

During the past decade a number of new date gardens were planted in the Arava Valley, which stretches from the Dead Sea to the Red Sea in southern Israel. The main varieties planted were Khadrawi, Zahidi and Deglet Noor. When cropping started, thinning methods common in the well established date-growing districts of Israel (Jordan and Bet She'an Valleys) were introduced (1). The size of fruit harvested in the Arava region was smaller than that from the north. I obtained no satisfactory results in controlled thinning experiments conducted for a number of years. My impression was that fruit set in this desert region was much heavier than in other areas and, therefore, severe thinning methods would have to be introduced. Observations on a number of varieties in different gardens suggested that fruit set and natural fruit drop vary even within the same region. To clarify the matter, a study of natural fruit drop in the 3 varieties was carried out during 1966 and 1967 in 4 gardens. The aim of the study was to verify the impression that the rate of fruit drop is specific both to the variety and to the garden in which it grows. If this were indeed the case, individual thinning methods would have to be developed for each garden to achieve similar results, since the number of fruits per bunch is known to have a great influence on the size of individual fruits (4).

OBSERVATION METHODS

The study was carried out in 4 gardens: at Elot (near the Red Sea), Yotvata (25 miles north of the Red Sea), Ne'ot Hakikar (6 miles south of the Dead Sea) and 'En Gedi (on the west coast of the Dead Sea). In each garden, inflorescences flowering on the same day were chosen on different trees. Khadrawi bunches were thinned in both years by removing the central strands. Zahidi was thinned in 1966 by removing the central strands; in 1967, in addition to removal of central strands, the tips of the remaining strands were cut back. Thinning of Deglet Noor consisted of tip-cutting and central strand removal in both years. Bunches were thinned to different degrees in different gardens at pollination time or soon after it. The bunches were enclosed by wire nets which were tied to the fruitstalk a few days after emergence of the inflorescence. Flowers, fruitlets and fruit shed into the nets were counted once every 2 to 3 weeks in 1966, and monthly in 1967. The study lasted from spathe opening to the beginning of the khalal stage. The count did not include partially ripe Zahidi fruits which dropped at the beginning of ripening. The reason for this drop is unknown and will not be discussed here.

RESULTS

Tables 1-3 give the details on thinning and drop for each variety; Fig. 1 shows the cumulative drop curves for each variety in the 4 gardens. Since the trend of the curve was very similar in both years, only the 1966 figures are given.

Khadrawi: The trend in the pattern of fruit drop was found to be similar in the 4 gardens. Fruitlet shedding began 25 to 30 days after flowering, at which time one enlarged carpel in the tricarpellary ovary was already distinguishable. Both types of flower dropped at this date, i.e., those with 3 equal and small carpels, and those with one enlarged carpel. The latter condition, enlargement of one carpel, may be due to parthenocarpic development occurring without pollination², and is therefore not necessarily a sign of fruit set. Fruitlet shedding continued at a fast rate, with most of the fruitlets consisting of single developed carpels and only a few of 3 developing carpels. Both of these types of fruit may be parthenocarpic, which may be due to either a faulty ovule or a lack of pollination. Since 75% of all fruits due to drop up to maturity have dropped by the time excess bunches are removed at bunch-tying time (60-70 days after flowering), the discerning grower can estimate what the total drop will be and can act accordingly. If he knows the optimal number of fruits the trees can bear, he can regulate the number of bunches and, if necessary, can increase the degree of thinning to achieve optimal results.

Zahidi: The course of fruit drop in this variety varied among gardens from quite low to relatively high (Table 2). The pattern of fruit drop was similar to that found in Khadrawi in gardens where the total drop was high. In such cases, the suggestions given for Khadrawi, for amending the degree of thinning at bunch-tying time, may be applied also to Zahidi. In gardens where the total drop was low, it continued slowly throughout the season and in such gardens alternative procedures for bunch thinning might be used. If the garden is known for its low drop, the trees must be thinned heavily from the start. However, if the history of the garden is not known and at bunch-tying time one finds that the drop so far has been low, one may assume that the total drop will be low and one can increase thinning in the bunches.

Deglet Noor: This variety is characterized by 2 waves of heavy fruit drop at definite times. The inexperienced grower may well be startled by the sudden drop of large quantities of flowers and fruit. This phenomenon looks unhealthy in comparison with the gradual drop of Khadrawi and Zahidi fruits as described above.

The first wave of fruit drop started 30 to 35 days after flowering and lasted about a month. The second, or "June", drop started approximately 100 days after bloom and also lasted about a month. As can be seen from Fig. 1, the rates of drop during the 2 waves were not similar in the gardens compared. In Yotvata, more flowers dropped in the first wave than did fruits in the second, while at 'En Gedi, the opposite was true. Both cases cause problems for the grower. On seeing a heavy drop of flowers (as in Yotvata), the grower thinks he has a light set and will fear a low yield after the June drop. On the other hand, if few flowers are shed in the first wave (as in 'En Gedi), the grower will become discouraged when he sees large numbers of big fruits dropping later. The experience of 2 years showed, however, that the final percentage of drop is similar in both cases. The author feels that making a decision to amend the degree of thinning at bunch-tying time is very complicated in the case of Deglet Noor. Each grower must get to know the rate of natural fruit drop in his garden; from this information, he can decide in advance the degree to which he should thin his trees.

On June 24, 1966, at 'En Gedi 250 Deglet Noor fruits which dropped from different trees during the "second wave" were examined. The seeds were cut open and it was found that only 4 of the 250 did not contain an embryo, and the other 246 seeds were complete. It seems that, in spite of the presence of an embryo, fruit was shed because the trees were overloaded.

CONCLUSIONS AND DISCUSSIONS

Although technical difficulties made it impossible to obtain complete data for all varieties in all gardens in both years, the following main conclusions may be drawn:

1. The rate of natural fruit drop varies with the variety, being highest in Deglet Noor, intermediate in Khadrawi and lowest in Zahidi.
2. The rate of drop in one variety may be similar or may vary from garden to garden.
3. The rate of drop in each variety was similar in both seasons in any one garden.
4. The degree and method of thinning do not influence the percentage of natural drop. (Note especially the data for the 3 varieties in the 'En Gedi garden in both years.)
5. The pattern of the drop over the season was different for the 3 varieties, but for any one variety the pattern was similar in both seasons.

Some of these results are found in earlier thinning experiments where counts of fruit set and shed were made. Nixon's work (2) showed that the number of fruits set per strand does not vary if bunches are thinned at flowering time or in June. Other experiments (3, 5) also show that setting percentages do

¹Contribution from The Volcani Institute of Agricultural Research, Bet Dagan, Israel. 1969 Series; No. 1534-E. Invitational paper presented by R. W. Nixon.

²Reuveni, O. 1966. Investigation on the anatomy and physiology of parthenocarpic and seed-bearing fruits. Ph.D. Thesis submitted to the Hebrew University of Jerusalem. (Hebrew, unpublished.)

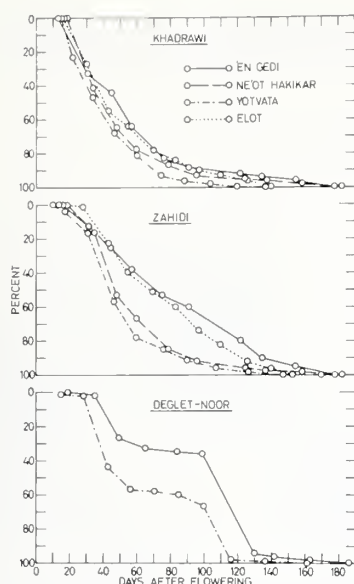


FIG. 1. Cumulative flower, fruitlet and fruit drop expressed as percentage of total dropped during period from flowering to ripening (1966.).

not vary when different thinning formulas are employed. All these findings corroborated our work, where we found that the degree of fruit set and natural drop are fixed for each variety in each garden. We could find no satisfactory explanation for the differences in the degree of drop in one variety in different gardens. Though we have no direct evidence, we postulate that a number of flowers have a defective ovule *a priori* and therefore cannot set fruit. If this possibility is accepted, it may be assumed that it is determined by growing conditions in the garden. It is therefore important that every grower should know the rate of natural fruit drop in each plot of his gardens, and with this information he can decide whether to thin heavily or lightly. A good example of the application of such knowledge is the 'En Gedi garden, in which Zahidi was found to have a low percentage of drop in 1966. Very heavy thinning was introduced in 1967 (Table 2), with the result that fruit size was greatly improved and yet the percentage of natural fruit drop remained unchanged.

On summarizing the results of the observations described, we find many things still unclear, such as the reason for the different behavior of the different varieties. However, the fact that the final rate of fruit drop is more or less fixed for both variety and garden enables the grower to determine the correct degree of thinning, once the drop-rate and the optimal number of fruits per bunch and per tree are known.

SUMMARY

The pattern of natural flower, fruitlet and fruit drop was observed in the date palm varieties Khadrawi, Zahidi and Deglet Noor from flowering to maturation. The main facts established are that (a) the rate of natural fruit drop varies with variety and garden; (b) the rate of drop is more or less fixed for each variety in each garden; (c) the rate of drop does not depend on the degree of thinning or the time thinning is carried out; and (d) the pattern of fruit drop throughout the season is specific for each variety.

TABLE 1. Details of observations on and thinning of Khadrawi date bunches, 1966 and 1967 (averages)

Site:	'En Gedi		Ne'ot Hakikar		Yotvata		Elot
Date of planting:	1954		1960		1958		1959
Year of observation:	1966	1967	1966	1967	1966	1967	1966
No. of bunches under observation	7	10	6	10	14	11	8
Dates of flowering	Feb. 23	Mar. 29	Feb. 18	Mar. 29	Mar. 5	Apr. 28	Feb. 17
No. of strands/bunch before thinning	95	97	62	69	83	71	68
No. of strands/bunch after thinning	61	40	42	40	50	41	42
No. of flowers/bunch before thinning	4515	4521	2214	2645	3433	2505	2870
No. of flowers/bunch after thinning	3110	1929	1534	1622	1997	1495	1940
Flowers thinned, per cent	31	57	31	39	42	40	32
No. of flowers/bunches shed	1270	923	947	997	646	481	542
Natural drop, per cent ^{1,2}	41b	48	62c	61	33ab	34	28a

¹ Figures followed by different letters are significantly different at the 5% level.

² according to the t-test there was no significant difference between the 1966 and 1967 at 'En Gedi.

TABLE 2. Details of observations on and thinning of Zahidi date bunches, 1966 and 1967 (averages)

Site:	'En Gedi		Ne'ot Hakikar		Yotvata		Elot
Date of planting:	1954		1960		1958		1958
Year of observation:	1966	1967	1966	1967	1966	1966	1966
No. of bunches under observation	10	14	9	9	15	7	7
Dates of flowering	Feb. 22	Mar. 25	Feb. 18	Mar. 20	Mar. 1	Feb. 17	Feb. 17
No. of strands/bunch before thinning	79	90	61	57	62	67	67
No. of flowers/bunch before thinning	4530	5150	2510	2186	2630	3798	3798
No. of flowers/bunch after thinning	3060	1500	1400	1188	1430	2456	2456
Flowers thinned, per cent	32	71	44	45	46	35	35
No. of flowers/bunch shed	598	319	626	551	486	378	378
Natural drop, per cent ¹	21a	21	45c	46	34b	15a	15a

¹ Figures followed by different letters are significantly different at the 5% level.

TABLE 3. Details of observations on and thinning of Deglet Noor date bunches 1966 and 1967 (averages)

Site:	'En Gedi		Yotvata		Elot	
Date of planting:	1954		1958		1958	
Year of observation:	1966	1967	1967	1966	1966	1966
No. of bunches under observation	8	10	9	15	15	15
Dates of flowering	Feb. 22	Mar. 30	Apr. 6	Mar. 9	Mar. 9	Mar. 9
No. of strands/bunch, before thinning	63	59	66	55	55	55
No. of flowers/bunch, before thinning	4968	3601	5135	4100	4100	4100
No. of flowers/bunch, after thinning	3283	1652	2024	2340	2340	2340
Flowers thinned, per cent	33	54	59	43	43	43
No. of flowers/bunch shed	1737	786	1274	1020	1020	1020
Natural drop, per cent ^{1,2}	53a	48A	63B	44b	44b	44b

¹ Figures followed by different letters are significantly different at the 5% level (lower case, 1966; upper case, 1967).

² According to the t-test there was no significant difference between 1966 and 1967 at 'En Gedi.

LITERATURE CITED

- Hilgeman, R. H. 1953. Observations on date culture in Israel. Date Growers' Inst. Rep. 30: 17-18.
- Nixon, R. W. 1935. Bunch thinning experiments with Deglet Noor dates. Date Growers' Inst. Rep. 12: 17-19.
- _____. 1936. Further experi-

ments in fruit thinning of dates. Date Growers' Inst. Rep. 13: 6-8.

- _____. 1940. Fruit thinning of dates in relation to size and quality. Date Growers' Inst. Rep. 17: 27-29.
- _____. 1951. Fruit thinning experiments with the Medjool and Barhee varieties of dates. Date Growers' Inst. Rep. 28: 14-20.

SORTING AND PROCESSING MECHANICALLY HARVESTED DATES

C. C. HUXSOLL and D. REZNIK¹

Western Regional Research Laboratory, Agricultural Research Service,
U. S. Department of Agriculture, Albany, California 94710

Because of the decreasing supply of farm labor, the date industry, like most other agricultural industries, has necessarily turned to increasing mechanization of cultural practices. Since harvesting dates required relatively large amounts of labor, this operation was one of the first to be mechanized. While the mechanical harvesting system which evolved is adequate for harvesting the dates, it has led to problems in sorting and processing dates prior to packing.

When dates are hand-picked, some sorting occurs implicitly, but when harvested mechanically, very mixed lots of dates are delivered to the processing plants. Therefore, while the mechanical harvesting system reduces the amount of labor required in the field, it increases labor in grading. In addition, when lots of dates are very non-uniform, it is difficult to make a good separation even though an unreasonably high number of sorters are employed.

To alleviate some of these problems, we have explored several means of mechanically sorting field-run dates at the Western Regional Research Laboratory in Albany. To begin the discussion of sorting, we might analyze what one does when hand sorting. Several characteristics of a date indicate its quality. One may visually observe its size, color, shape, and surface characteristics. In addition, one may feel it to determine the texture and obtain more information about its surface character. When rapidly hand sorting, one combines this information, somewhat subconsciously, and makes a judgment on the quality of the date. When combined, this information may be indicative of the moisture content, degree of maturity, density, or other factors not readily determined by sight or feeling.

When devising automated sorting systems, one must seek characteristics which are readily determined by machines and correlate them with the quality grades of the dates. It is unlikely that any one physical characteristic could be found which would exactly relate to the quality grade. Instead, one would expect that several physical properties would have to be sensed, as in hand sorting, and with the information from several sensors, the overall quality level established.

Sizing. One of the most obvious physical properties of dates, and simplest to determine, is the size. The equipment for doing this is usually simple to build and cheap to operate. However, it must be of the proper type. Since dates are soft and easily deformed, the sizer should be one which will not substantially damage or alter the shape of the dates. Fig. 1 shows a simple diverging roll sizer. Dates fed onto the inclined rollers at the top move down the incline. The separation of the rollers increases toward the bottom, and the dates fall between them when the separation becomes greater than the diameter of the dates. To orient the dates properly and to minimize dam-



FIG. 1. Pilot model of diverging roll sizer.

EFFECT OF SIZE SEPARATION



FIG. 2. Field-run dates separated into 4 size fractions by diverging-roll sizer.

¹ Present address: Technion-Israel Institute of Technology, Haifa, Israel.

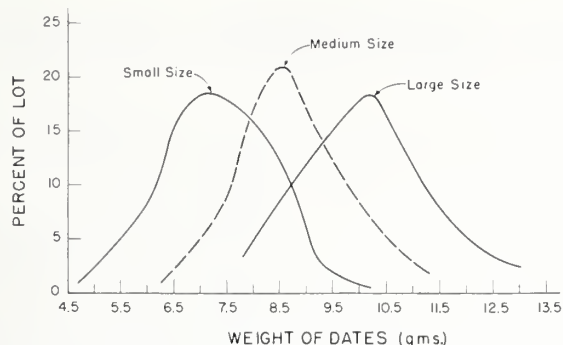


FIG. 3. Distribution of individual date weights in sized fractions.

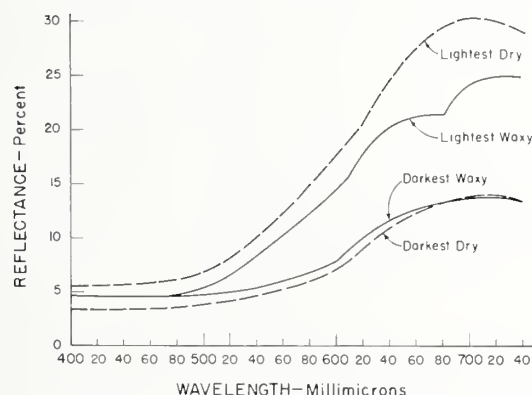


FIG. 4. Reflectance curves of darkest and lightest appearing dates in hand-sorted lots of waxy and dry dates.

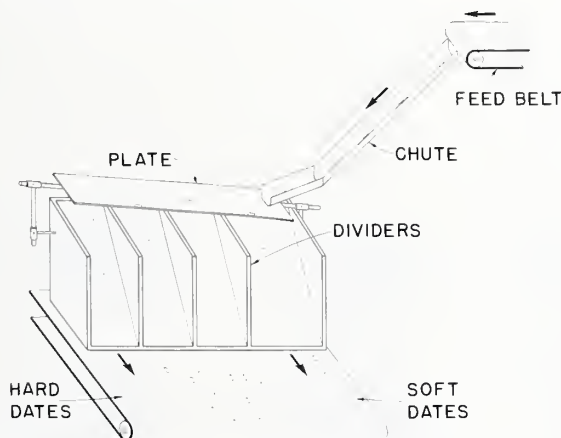


FIG. 5. Schematic diagram of a resilience separator for dates.

age, the rollers rotate in opposite directions, imparting an upward lift to the dates. Fig. 2 shows a lot of field-run dates which has been size-graded into 4 fractions. The very small dates are either unpollinated or of very poor quality—essentially culls. The next smallest are almost entirely sound fruit, but very dry, and all would require additional processing. The next size grade contains a mixture of waxy and dry dates but very few naturals. This size grade needs additional sorting. The largest size grade contains essentially no dry fruit. It is primarily waxy fruit with a few naturals. Fig. 3 shows the weight distribution of the various size fractions. The very small, or cull, fraction is not included, but the distributions of the 3 lots of sound fruit show that while a substantial separation has been made, there is still much overlapping of the distribution curves.

Color. Dry dates usually appear lighter in color than waxy or natural grade

dates, and one would therefore be inclined to try color sorting for additional separation of sized fractions. Reflectance curves were run using a recording spectrophotometer on lots of dates which had been hand graded. Measurements were made of those which appeared to the naked eye to be the lightest and darkest dates in each lot, in addition to dates which appeared to be of average color in each lot. The dates were pitted and flattened against the target in the spectrophotometer to measure the reflectance values of their outer surfaces.

The problems encountered in color sorting of dates are evident from an examination of Fig. 4. Here it is seen that while the lightest dry date shows a consistently higher reflectance than the lightest waxy at each wavelength, the lightest waxy has much higher reflectance than the darkest dry date. The darkest waxy and the darkest dry dates show similar reflectance values at all wave-

lengths. Although not shown in Fig. 4, the average dates in each lot exhibited very similar reflectance values. While some sorting may be accomplished by using a color sorting system, the degree of sorting would probably not be adequate to warrant such a sophisticated sorting technique.

Specific gravity. The density, or specific gravity, of dates is some indication of quality. High quality dates have a high density, especially those which have not quite reached full maturity or have not started to dry before reaching full maturity. However, when dates become dry, the skin often separates from the flesh, leaving an air pocket. When dates contain such entrapped air pockets, flotation measurements of whole dates result in erroneous indications of the actual density of the date flesh. Therefore, differential flotation separation is useful for quality sorting of immature dates, but it will not work on lots of dates which have fully matured or dried.

Resilience. One property of dates which does reflect their quality is resilience. It is well known that high quality mature dates have a softer texture than hard dry dates. This difference in texture may be measured by the difference in the resilience of the dates. Dry dates are more resilient than waxy dates which are, in turn, more resilient than natural dates. This means that when a dry date and a waxy date are dropped from the same height, the dry date will bounce more than the waxy date. Separators based on this principle have been used on commodities such as seeds. Fig. 5 is a schematic diagram of a resilience separator for dates. Dates fed onto a chute slide down the chute and fall onto an inclined metal plate. Soft dates do not bounce and quickly fall from the plate. Dry dates bounce along the plate before falling off. This effects the separation. When combined with previous sizing, resilience separation results in grades of dates which require very little additional sorting.

Immature date harvest. In our early work on automating date processing, we considered the possibility of artificially ripening immature dates. Such a harvest has some advantages over delaying the harvest until all the dates have fully ripened or dried. When dates are harvested at an immature stage, insect infestation is greatly reduced, drop loss in the gardens is substantially less, and density relates to quality so that the dates are easily sorted by differential flotation. The disadvantage of the immature harvest is that the dates are more perishable in this stage and require refrigerated storage. If the dates are too immature, many will not have a satisfactory flavor when artificially ripened, and the overall yield may be less if the sugar content does not reach a satisfactory level.

The ripening process used was the freeze-heat process. We found that a freezing temperature of 0°F gave optimum results, and heating at about 100°F seemed to give the best results for most lots. We also found that tempering the frozen dates at 34°F for 1-2 days prior to heating improved the uniformity of the ripened dates.

Fig. 6 shows lots of dates that were artificially ripened from the red, or khalal stage. All the lots had a good appearance similar to natural dates. Solutions of 10 to 20% sucrose were used

for the flotation sorting prior to artificial ripening. To be a satisfactory final whole-date product, the dates should have a density at least equivalent to that of a 15% sucrose solution. That is, when placed in a 15% sucrose solution they should not float. The least dense dates, those which floated in a 15% sucrose solution, could be seen to have a thinner layer of flesh when the pit was removed. These would probably be used as product grade dates. The effect of tempering could be seen by the additional breakdown of the cellulose fibers surrounding the pit when the dates were tempered for 2-6 days. There appears to be no advantage to the 4- and 6-day tempering periods; however, the longer tempering periods did not result in any adverse effects.

While harvesting the entire crop before any of the dates were naturally ripe would be neither practical nor desirable, it may be desirable to harvest the crop when most of the dates are tree-ripened or dried but while some are still in the red stage. In 1967 we harvested bunches of dates at 3 levels of maturity and found that when about 75-80% of the dates on the bunches were ripe and the remainder were still in the red stage, the entire lot of fruit could be processed to a high quality product. More extensive studies would be required to select an optimum harvest time, but from these initial observations it appears that overall quality is enhanced when the harvest is made at a slightly immature rather than an overmature stage.

Vacuum hydration. To improve the processing of very dry dates, we have studied the characteristics of vacuum hydration. This technique is already being used to some extent, but with more controllable equipment, more precise moisture levels may be obtained. Fig. 7 is a schematic diagram of a vacuum hydrator. The unit is similar to a retort used for heating canned foods with high pressure steam. The per cent increase in moisture during vacuum hydration is directly dependent upon the vacuum level obtained; therefore, it is possible to attain quite precise final moisture levels. Vacuum hydration, in addition to moisture control, has these advantages (1) it is rapid, (2) it does not require long exposures to high temperatures, and (3) it tends to level the moisture variations between the dates. This type of vacuum hydration should be used only for dry dates. Other hydration procedures are more suitable for waxy dates.

Field tests. In order that the industry may have an opportunity to determine the feasibility of using some of the sorting techniques described here, we will have pilot models of the diverging roll sizer and the resilience separator available for the 1969 harvest season. These will be portable units designed to handle about 500 lb. per hr. We want any interested packer to use this equipment to ascertain its feasibility for his particular operation. He will then be able to decide on the size and type of units most suitable for his own plant.

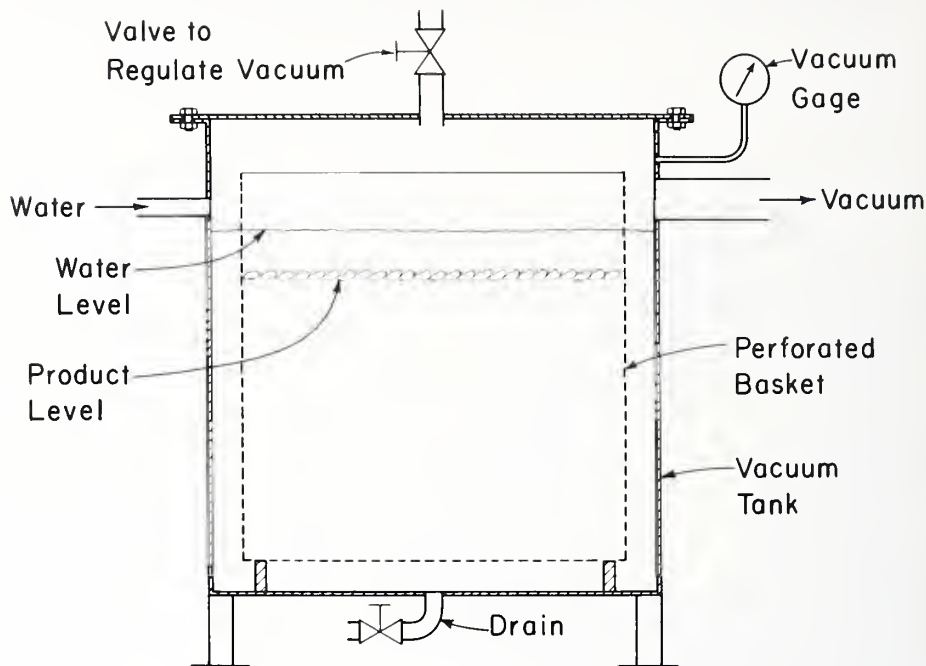


FIG. 6. Artificially ripened dates, showing the effects of tempering and density.

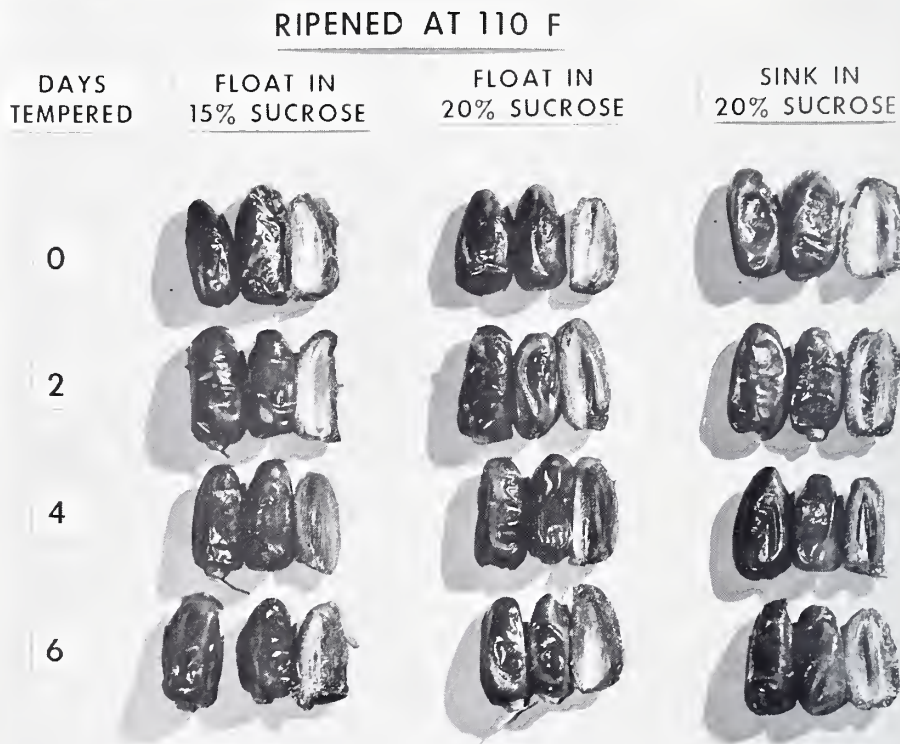


FIG. 7. Schematic diagram of a batch-type vacuum hydrator for hydrating dry dates.

GROWTH, DEVELOPMENT, AND SOFTENING OF THE DEGLET NOOR DATE FRUIT¹

C. W. COGGINS, JR. and J. C. F. KNAPP

Department of Horticultural Science
University of California, Riverside 92502

A reasonably clear picture of development of the Deglet Noor date from the time of pollination until the soft condition is reached can be obtained from a review of the literature. Although pertinent information occurs in numerous reports, most of the available knowledge concerning morphological and chemical changes associated with development of the Deglet Noor date is contained in the reports by Long and Rygg. These two reports present comprehensive studies of anatomical (4) and chemical (7) changes associated with the kimri (green), khalal (pink), and rutab (softening) stages. Until recently the various conditions that exist in the tamar stage (cured) have not been subjected to a comprehensive anatomical and chemical study. We hope that this article, along with recent reports (1, 2), will provide a better understanding of the tough and tender grades that exist in the tamar stage.

Various investigators have suggested that the tough grades of dates result from rapid desiccation. The implication is that developmental processes are arrested at an early stage of ripening and that certain chemical and anatomical changes associated with softening do not proceed far enough for the desirable soft texture to occur. Recent anatomical studies (1, 2) show that most cell walls are intact in tough grades and that most cell walls are not intact in soft grades. Thus, it appears that cell wall dissolution has not proceeded very far in firm grades. This lack of cell wall dissolution may be due to desiccation.

Apart from differences in moisture content and in relative amounts of reducing and non-reducing sugars, no clear differences in major constituents have been reported among the various grades of Deglet Noor dates. Although a comprehensive study of chemical changes associated with development was reported by Rygg (7), we decided to re-examine chemical changes during development using the same analytical methods that we employed in our study of grades. Thus, this study considers chemical changes during development as well as chemical differences that exist among grades. This article also considers changes that occur in nuclei during development.

MATERIALS AND METHODS

To obtain information concerning growth rate and chemical changes, we harvested fruit at 2-week intervals during 1968 from a tree located at the U.S. Date and Citrus Station, Indio, Cali-

fornia. While a single tree is far from sufficient to determine the average changes that prevail in a given year, the purpose of this study was to examine correlative changes, and tree-to-tree variability was intentionally avoided.

Three different fixation fluids were used for material prepared for anatomical study: formalin-acetic acid-alcohol (FAA); Navashin's solution; and Zirkle's modification of Erlki's fluid. In each case the tissue was dehydrated in an ethyl-tertiary butyl alcohol series, infiltrated and embedded in a commercially available paraffin preparation (Paraplast), sectioned at 10 microns and stained with safranin and fast green.

For chemical analyses, the flesh of date fruits was passed through a food chopper, frozen in liquid nitrogen, partially freeze-dried to remove most of the moisture, then vacuum dried (20mm Hg) at 60°C. The sample was then pulverized in a ball mill.

Moisture determinations were made on sub-samples of tissue after it had passed through the food chopper. These samples were immediately weighed, frozen in liquid nitrogen, partially freeze-dried, then completely dried at 20mm Hg and 60°C and weighed again.

Sugars were extracted under reflux conditions with 80% ethanol. Samples contained approximately 0.3g of tissue and were extracted for 4 hrs. Since the dry powders are hygroscopic, it was necessary to take special precautions to obtain accurate dry weights of samples to be extracted. Appropriate quantities of date powder were transferred to previously extracted (80% ethanol reflux), vacuum dried, tared paper thimbles. The samples were then vacuum dried for 4 hrs. and weighed.

Reducing sugars (glucose plus fructose) were estimated by the Nelson-Somogyi colorimetric method (6), and the glucose portion of reducing sugars was determined by direct assay with the glucostat method (9). Sucrose levels were determined by using the glucostat method to measure the increase in glucose following invertase treatment of extracts.

DEVELOPMENT OF THE DEGLET NOOR DATE

Fruit grew in diameter until July 18, increased in length until August 1 (Fig. 1), and thus attained maximum volume by August 1. At this stage of development a definite change in color, which preceded the khalal stage, occurred.

Calyx fresh weight remained stable at approximately 0.13g throughout this period. Fresh weight of the pit (seed) increased from 0.15g on June 6 to a high of 1.5g on July 18. Between July 18 and August 15, pit weight remained constant and then gradually decreased to approx-

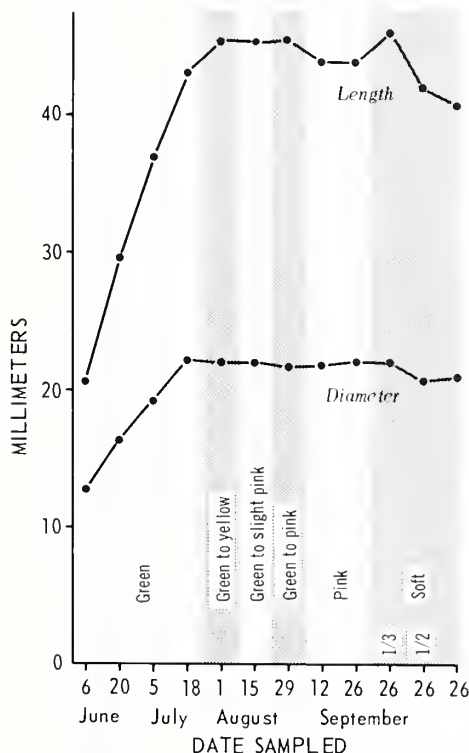


FIG. 1. Changes in length and diameter of the Deglet Noor date fruit during growth, development, and ripening.

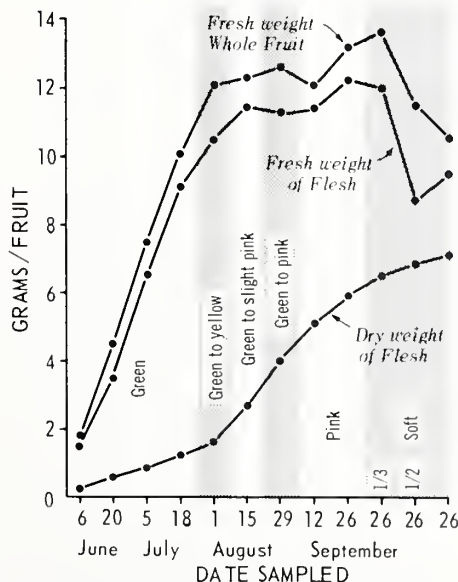


FIG. 2. Fresh weight and dry weight changes during growth, development, and ripening.

¹Report of work done under Contract No. 12-14-100-8871 (74) with the U.S. Department of Agriculture. The contract was supervised by the Western Utilization Research and Development Division, Agricultural Research Service.

imately 0.75g in the soft rutab date on September 26. This decrease in fresh weight probably is due to a reduction of moisture.

The amount of moisture in the flesh increased rapidly during volume growth. After maximum volume was reached, the amount of moisture decreased slowly until softening started and then decreased rapidly. While maximum fruit volume and maximum quantity of water were attained by August 1, dry matter continued to accumulate rapidly until much later (Fig. 2). In fact, less than one-third of the dry matter had accumulated by the time maximum fruit volume had been reached. This agrees with data presented by Rigg (7).

Obviously, large quantities of assimilates moved into the fruit at a time when the net amount of water was decreasing (Fig. 2). Apparently, translocation into the fruit continued after softening was well underway (Fig. 3). Although considerable cell wall dissolution has occurred by the time the date is in the early stages of softening (2, 4), our histological studies suggest that vascular bundles are in good structural condition in the fully soft rutab date. Thus, the vascular system appears to be relatively stable, structurally, and the transport mechanism apparently is functional even when surrounding tissue is in an advanced stage of degeneration.

Alcohol-insoluble solids include cell wall polymers, proteins, condensed tannins, and an array of other compounds (7). Since the bulk of this fraction consists of cell wall polymers and condensed tannins, it is possible to interpret major quantitative changes in terms of cell wall synthesis, cell wall degeneration, and changes in solubility of tannins.

The alcohol-insoluble fraction (Fig. 3) increased until August 29 and then remained constant until softening occurred. Until the beginning of softening, the increase probably was due to accumulation of cell wall constituents. From June 6 until August 1 the observed increase per fruit probably was due to cell wall synthesis related to increase in fruit volume. Subsequent to this, the increase can be attributed to further cell wall synthesis related to increases in thickness of walls rather than increases in cell size. According to Long (4) and to our anatomical studies (1, 2), dissolution of cell walls occurs during softening. This probably accounts for the dramatic decrease in alcohol-insoluble solids during the change from a turgid fruit to a fruit that is partially or fully soft. Although it is possible to arrive at a rationale for the decrease in soluble material with softening, the fact that all three degrees of softened fruit contained approximately the same quantity is not as easy to understand until histological examinations are considered. Histological studies, however, indicate that extensive cell wall dissolution is present in the partially soft fruit and that only a minor increase in dissolution is seen in the fully softened tissue. Thus, substantial differences in quantity of insoluble solids among these stages would be inconsistent with the lower than actual and that the magnitude of error introduced by change in solubility of tannins may vary with the extent of softening. While we observed a substantial decrease in insoluble solids, Rygg (7) reported that no decrease per fruit occurred during ripening of the

Deglet Noor date fruit. Perhaps this lack of agreement is due to the different analytical procedures used, but we believe that the decrease in insoluble solids that we obtained is consistent with the histological evidence for cell wall dissolution.

The information obtained for insoluble solids is presented as quantity per fruit, per cent dry weight and per cent fresh weight in Fig. 4. These 3 curves reveal that it is unwise to base conclusions about development on percentages unless extreme care is utilized in evaluation of the data. This is true because the data minor structural differences observed through the microscope.

Rygg (7) reported that the tannin of the immature date appears in the alcohol-soluble fraction and that in mature dates it appears in the insoluble residue. In

decrease in insoluble solids as being due to cell wall dissolution, it is important to recognize that the estimate will be pertinent to an organ that is growing at various rates during the time studied. During this time, certain constituents increase, others decrease, and some constituents increase substantially and then decrease significantly. Although percentage data may be extremely valuable for certain comparisons, we feel that the best data to use for developmental considerations are those presented on a per fruit basis.

As an illustration of the different first impressions left by these data, the following initial conclusions are presented for insoluble solids: (1) based on quantity per fruit, insoluble solids increased until softening started and then decreased; (2) based on dry weight, the percentage insoluble solids decreased during growth and development but did not change during softening; and (3) per cent insoluble solids did not change appreciably on a fresh weight basis during the period of examination.

Nonsugar alcohol-soluble solids (Fig. 3) gradually increased to approximately 0.2g by September and then suddenly increased substantially in all fruit harvested on September 26. While the increase in softened fruit can be explained as due to breakdown of cell wall polymer material, we are at a loss to explain the sudden apparent increase in turgid-pink fruit. It is possible, of course, that this increase represents a stage of softening that we were unable to detect by sight or touch.

Sucrose, glucose, and fructose were the only sugars detected when alcohol extracts were examined by paper and thin-layer chromatography. These examinations were restricted to June 6, August 1, and September 26, but since no evidence of other sugars was found, it is safe to assume that only three free sugars are present at appreciable levels in the flesh of Deglet Noor dates. Similar examinations of various grades of cured dates gave the same three sugars.

Our quantitative estimates of sugars (Fig. 5) agree with those reported by Rygg (7). As anticipated, the quantity of sugar was low in young, small fruit and increased rapidly during growth. When fruits had reached full volume, sugar was present at the relatively low level of 0.8-0.9g per fruit. Subsequently, the rate of accumulation increased and remained high until softening started. While the rate of accumulation decreased during softening, we wish to emphasize the fact that accumulation continued during the softening process.

The relative concentrations of the three sugars varied during development of the fruit. Reducing sugars accounted for 85-90% of the sugar during June and then, as the quantity of sucrose increased faster than reducing sugars, the relative amount of reducing sugars dropped to less than 20% during the khalal stage. During the softening the quantity of reducing sugars increased. As discussed later in this article, our hypothesis is that the increase in reducing sugars is due to enhanced invertase activity resulting from a loss of integrity of membrane systems.

We found that nearly equal amounts of glucose and fructose were present early in development and that unequal amounts were present in softened fruit. This suggests the need for biochemical

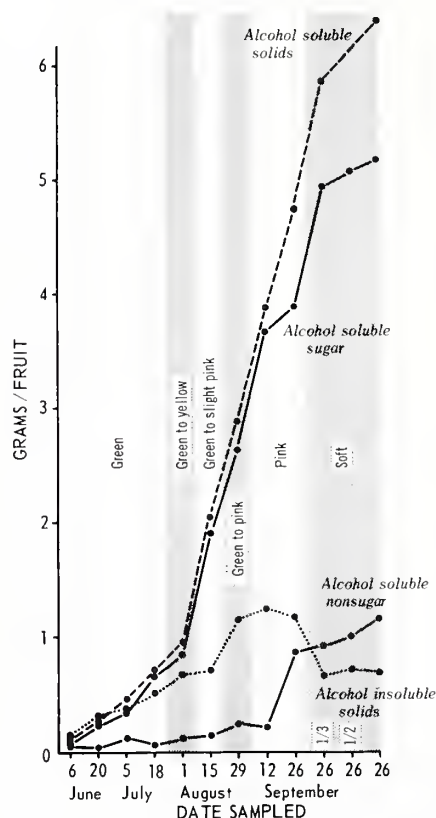


FIG. 3. Quantitative changes in various dry matter fractions during growth, development, and ripening.

an examination of green, pink, ripe, and stored fruit, Maier and Metzler (5) found that the insoluble tannins per fruit increased substantially between the green and tree-ripe condition. Although the largest increase occurred between the pink and ripe stage, a significant increase was seen between green and pink. They concluded that soluble tannin is synthesized during fruit growth and that the loss of soluble tannin and the increase in insoluble tannin seen during maturation is due to conversion of soluble to insoluble forms. While some conversion to insoluble forms occurred prior to softening, their data show that a considerable conversion occurred during softening. Thus, the decrease in insoluble solids reported in Fig. 3 represents the loss of cell wall polymers due to dissolution plus an increase from tannins. If one wishes to interpret the

studies on interconversion and utilization of sugars in the date fruit. The date system apparently would not involve complications normally introduced by starch. Lloyd (3) reported that dates contain a small amount of starch at about the time of pollination but none thereafter.

The only anatomical change reported by Long (4) during softening was cell wall dissolution. Our studies (1, 2) provide support for cell wall dissolution during softening, but we have also observed a marked change in the nucleus during the transition from a large green or pink-colored fruit to a partially or fully tree-ripe fruit.

In tissue obtained from green or pink-colored fruit, nuclei were relatively large and occurred in various shapes, and good stain differentiation existed within nuclei (the nucleoli, for example, were stained differently than other portions of the nucleus). Once softening started, however, staining properties and the shape of nuclei changed. Nuclei changed to perfect spheres, were considerably smaller, and were so deeply stained that nucleoli were difficult or impossible to discern. This same condition was apparent whether FAA or the two other fixatives were used. Although fixed tissue does not show exactly what existed in the fresh tissue, these relative differences are subject to interpretation, especially since the same story was obtained with the three fixatives. The change proceeded more rapidly in the outermost portion of the mesocarp, or at least a greater percentage of nuclei had changed at early stages of softening than in more interior regions of the mesocarp. By the time the tree-ripe stage was reached, well over 90% of the nuclei had changed to the small spherical-shaped units.

Whether cell walls are intact or cell wall dissolution has occurred obviously has a direct impact on structural strength. Although the condition of the nucleus is not directly related to structural strength, the fact that a substantial change in the nucleus occurs provides an important clue as to what probably permits softening to occur. We interpret the observable changes in the nucleus to be due to a loss of the semipermeable nature of the surrounding membrane. It is expected that a freely permeable mem-

brane would permit the nuclear protein to be denatured. Following protein denaturation, physical forces would cause a semi-fluid, non-metabolic particle to assume a spherical shape. Thus, we suggest that the observable difference in the nucleus is almost direct evidence that a change in membrane permeability had occurred and that it is likely that similar permeability changes occurred in all of the sub-cellular membranes. The loss of semi-permeable membranes would destroy intercellular and intracellular compartments and permit enzymes and

GRADES OF DEGLET NOOR DATES

The chemical and anatomical properties of tough and tender grades of Deglet Noor dates have not been as thoroughly studied as the kimri through rutab stages. In a review statement, Rygg (8) indicated that the dry-textured dates are harder and duller in appearance than good-textured ones. He also reported that the flesh is often whitish and has a lower pH, lower reducing sugar content, higher sucrose content and usually a lower moisture content than the flesh of good-textured dates. This brief statement, which appears to be an adequate statement of knowledge concerning known differences among firm and tender grades, indicates that further characterization of differences among grades is needed. Progress concerning

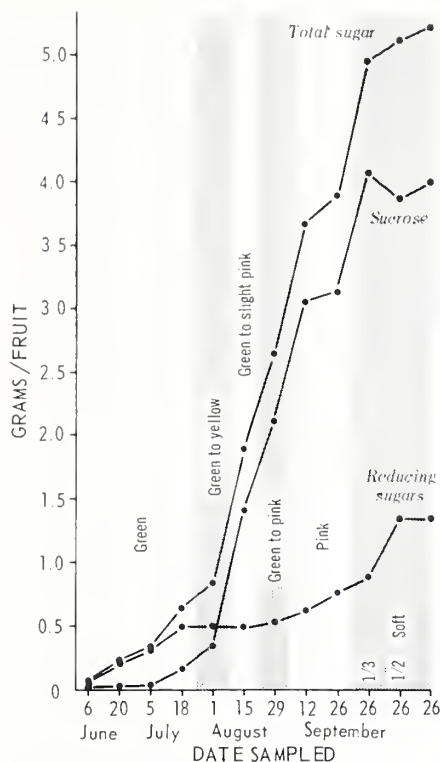


FIG. 5. Changes in quantity of sugars during growth, development, and ripening.

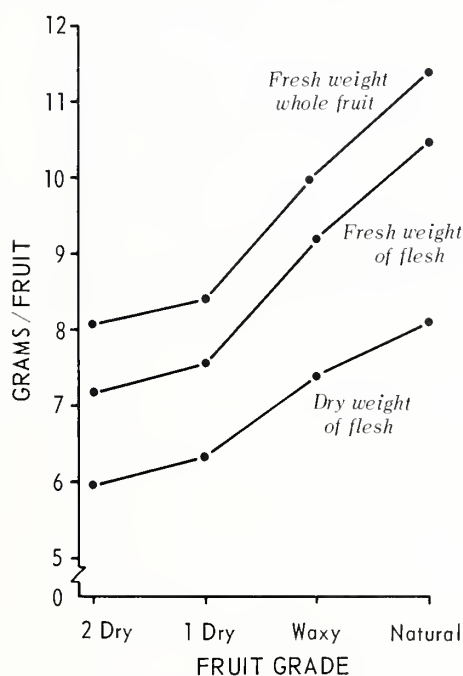


FIG. 6. Weight relationships among various grades of Deglet Noor date fruits.

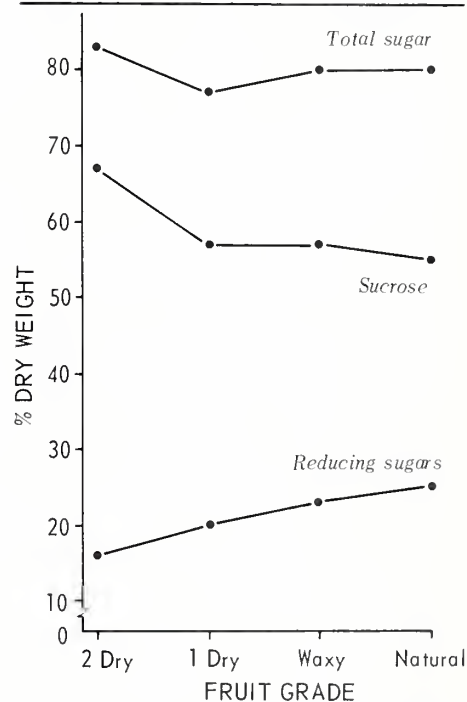


FIG. 7. Quantity of sugar in the flesh of various grades of Deglet Noor date fruits. Expressed as per cent dry weight.

anatomical differences is reported in earlier publications (1, 2). This section deals with a study of chemical composition.

Most of the reports in the literature indicate that little or no difference in total sugar exists between the soft and firm grades. In terms of total sugar as per cent dry weight, our results (1, 2, Fig. 7) support this conclusion. However, in terms of quantity of sugar per date (Fig. 8), our data do not support this conclusion. It is clear that dry matter per date (Fig. 6) and total sugar per date (Fig. 8) differ considerably among

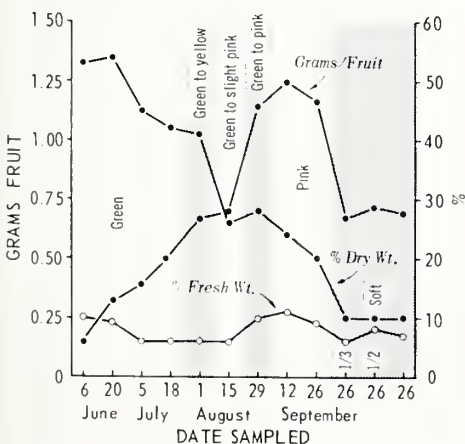


FIG. 4. Influence of methods of expressing data on apparent quantitative changes of insoluble solids during growth, development, and ripening.

the grades. This vast difference in conclusions emphasizes the dangers, which we discussed earlier, of evaluations that are based on percentages.

In the dry to soft series of grades, the soft (Waxy and Natural) grades contain considerably more dry matter and more sugar in the flesh than the firm (Number 2 Dry and Number 1 Dry) grades. Dry weight of flesh and quantity of reducing sugar appeared to increase consistently when going from firm to increasing degrees of softness. While total sugar was considerably higher in the soft grades, the quantity found in Number 2 Dry fruit was similar to the quantity found in the Number 1 Dry grade.

Sugar data show that sugars accumulate during development and softening and also during the interval between the time the date is fully softened (tree-ripe) and harvest time. Whether this transport of sugar into dates which become soft occurs throughout the time they are left on the tree or is restricted to a brief time subsequent to softening cannot be determined from our studies. Transport of sugar into dates that do not soften is considerably less than into softened dates.

CONCLUSION

Our anatomical investigations (1) and those by Long (4) show that considerable cell wall dissolution occurs during the preharvest softening process. Also, we have found that cell walls are intact in firm grades, as in turgid green-colored and pink-colored dates, and that cell walls are not intact in soft grades, as in soft tree-ripe dates (1, 2).

Changes in nuclei strongly suggest that the softening process involves the loss of intercellular and intracellular compartments by loss of integrity of membrane systems. We believe that the loss of membrane systems permits many enzyme and substrate molecules, which were at least partially separated, to come into contact. This sets the stage for preharvest softening. Whether softening occurs in a particular fruit is determined by presence or absence of favorable conditions for enzymatic reactions. A rapid reduction in moisture, for example, could completely cancel the dissolution of cell walls. Our data and data reported by Rygg (7) show that sugars continue to accumulate during softening. Our data also indicate that sugars continue to accumulate to a significant degree during the interval between the time the date is fully softened (tree-ripe) and harvest time. Sugar accumulation in the date that becomes dry and does not soften is much lower. This is probably a direct result of desiccation.

This prolonged transport indicates that the sugar transport system is functional in the softened date even though a majority of the parenchyma cells appear to be dead. In addition to the fact that transport obviously occurs during and subsequent to softening, histological studies show that the vascular system, which thoroughly permeates the flesh tissue, appears to be structurally intact at this stage.

Although we view softening of the flesh as being due to death of most of the parenchyma cells, we must consider that the vascular tissue is still functional and that the incoming sugar simply leaks into the surrounding tissue and is then subjected to some degree of inversion.

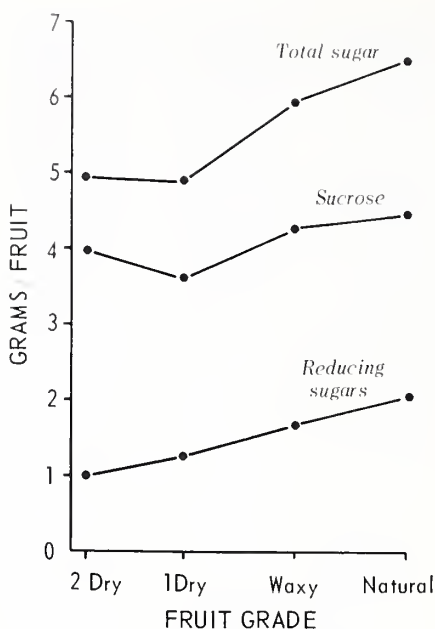


FIG. 8. Quantity of sugar in the flesh of various grades of Deglet Noor date fruits. Expressed as grams per fruit.

Our studies, along with the studies by Rygg (7), Long (4), and others, lead us to the conclusion that the difference between firm and soft Deglet Noor dates is controlled by degree and time of desiccation and that firm dates do not pass through the cell wall degeneration stage that is responsible, in part, for softening. The firm date is firm primarily because it has a lower moisture content and because it has a high percentage of intact cell walls. In addition to being firm and relatively dry, it has a lower dry weight, it does not contain as much sugar per fruit, and the ratio of sucrose to reducing sugars is high. It contains the enzymes that are responsible for softening, but the degree of activity is too low for a soft fruit to be formed.

ACKNOWLEDGMENTS

The authors wish to thank Alice L. Ricker and Sharon P. Goldstein for technical assistance in these studies.

LITERATURE CITED

1. Coggins, C. W., Jr., J. C. F. Knapp and Alice L. Ricker. 1968. Post-harvest softening studies of Deglet Noor dates: physical, chemical and histological changes. *Date Growers' Inst. Rep.* 45: 3-6.
2. ———, L. N. Lewis and J. C. F. Knapp. 1967. Progress report: chemical and histological studies of tough and tender Deglet Noor dates. *Date Growers' Inst. Rep.* 44: 15-16.
3. Lloyd, F. E. 1910. Development and nutrition of the embryo, seed and carpel in the date, *Phoenix dactylifera* L. *Mo. Bot. Gard. Ann. Rep.* 21: 103-104.
4. Long, E. M. 1943. Developmental anatomy of the fruit of the Deglet Noor date. *Bot. Gaz.* 104: 426-436.
5. Maier, V. P., and D. M. Metzler. 1965. Quantitative changes in date polyphenols and their relation to browning. *J. Food Sci.* 30: 1-5.
6. Nelson, N. 1944. A photometric adaptation of the Somogyi method for the determination of glucose. *J. Biol. Chem.* 153: 375.
7. Rygg, G. L. 1946. Compositional changes in the date fruit during growth and ripening. *USDA Tech. Bull.* 910. 51.
8. ———. 1954. Relation of dry texture in Deglet Noor dates to high spring temperatures. *Date Growers' Inst. Rep.* 31: 4-5.
9. Worthington Biochemical Corporation. Freehold, New Jersey. Method 1-A, September 1962.

SELECTIVE HARVEST AND FRUIT SEPARATION TRIALS WITH DEGLET NOOR DATES

E. G. VIS, G. K. BROWN and R. M. PERKINS¹

INTRODUCTION

About 80% of the 1968 crop of Deglet Noor dates was harvested by cutting mature bunches from the palms and mechanically shaking the fruit into bulk bins. Some of these bunches had unpollinated as well as pollinated fruit on them. Proper hand pollination, along with the placing of paper bags on blooms pollinated when rain or low temperatures were expected, has resulted in good fruit set and prevented the development of unpollinated fruit. However, the supply of workers for hand pollination has decreased in recent years so that the proper timing of pollen applications has become more difficult. Even in hand-pollinated palms, the percentage of unpollinated fruit may be a factor in fruit separation. In 1966 (2) in 5 of 12 gardens, the percentage of unpollinated fruit ranged from 6.1 to 13.6; the percentages were lower in the other 7 gardens. Some of the plots pollinated by aircraft had yields of pollinated fruit equal to yields from hand pollination even though 10% of their total was unpollinated. One of these plots produced 18% unpollinated fruit and yet equalled the production of the hand-pollinated plot. In 1967 (1) unfavorable weather conditions resulted in poor fruit set and a high percentage of unpollinated fruit in all gardens pollinated by aircraft.

Results from both hand and mechanical pollination experiments suggested that unpollinated fruit would probably continue to be present. The unpollinated fruit would not be picked if hand harvest methods were used, but mechanical harvest methods tended to remove most of the unpollinated fruit along with the pollinated fruit. Unpollinated fruit could only be sorted out by hand at the pack-

inghouse and thrown away. An exploratory investigation was conducted in 1967 to evaluate possible methods of reducing the hand sorting required to separate the unpollinated from the pollinated fruit.

FRUIT SEPARATION DURING HARVEST

Bunch Shaking Trials. The primary objective of these trials was to shake from the bunch a maximum number of pollinated fruit and a minimum number of unpollinated fruit. If successful, this would leave most of the unpollinated fruit in the field and thus minimize the sorting problem.

For test purposes, a date shaker producing a motion similar to that of the present commercial shaker was constructed so that the stroke was adjustable from 1/2 to 6 inches in 1/2 inch increments. Shaking frequency was varied by hydraulic pump speed and flow control valves.

Preliminary field tests were conducted to determine whether strokes shorter or longer than the 3/4 inch stroke of the present commercial shaker might result in pollinated fruit being removed and unpollinated fruit being left on the

bunch. We found that strokes of 1/2, 1, or 2 inches, at shaking frequencies up to 1200 cycles per minute (cpm), removed both types of fruit slowly, with no selectivity. Strokes of 3 inches or greater resulted in quick fruit removal at frequencies of 300 to 700 cpm. A field test was conducted to compare the selectivity of 3 and 6 inch strokes.

To simulate field conditions, bunches were cut using a commercial tower, lowered and dropped into a bulk bin. Nearly 50% of the fruit was removed by dropping and handling; this was similar to conditions for many mechanical harvesters. The bunches were then visually categorized into groups according to the per cent of total fruit on the bunch which was pollinated. Combinations of stroke and frequency were tested for selectivity by shaking several bunches from each group and comparing the results (Fig. 1). The length of the shaking period was set to give at least 15 cycles per bunch. Thus at 300 cpm, shaking time was 3 sec, and at 500 cpm it was 1-4/5 sec.

Results: The 6-inch stroke at 300 cpm was somewhat selective (when compared with the 3-inch stroke at 700 cpm), but the difference was not enough to be considered for commercial use. Many of the commercial shakers are operated at 1000

TABLE 1. Fruit removal summary of selective shaking tests of bunches with a high percentage of pollinated fruit

Shaker stroke	Frequency	Bunches	Avg bunch pollination	Poll. fruit removed as percentage of total fruit removed	Poll. fruit removed	Poll. fruit removed		
						Without calyx	With calyx	With calyx and strand tissue
inches	cpm ^a	no.	%	%	%	%	%	%
6	300	4	85	86	96	52	36	12
6	400	2	82	85	97	46	43	11
6	500	3	96	95	100	47	41	12
3	700	3	90	92	99	62	25	12
3/4 ^b	1080					56	37	7

^a Abbreviations: cpm = cycles per min; poll. = pollinated.

^b Data were obtained by sampling bins of commercially harvested fruit; specific bunch data were not available for columns 3 - 6, inclusive.

TABLE 2. Summary of water separation tests with pollinated and unpollinated date fruit

Date of test	Fruit Description	Water movement	Pollinated		Unpollinated		Immature		Total fruit in test
			Fruit	Sinkers Sp	Fruit	Floater Sup	Fruit	Sinkers	
			no.	%	no.	%	no.	%	no.
6 Oct. 1967	Day of harvest. Poorly pollinated bunch	None	10	80	10	100	10	100	30
17 Oct. 1967	Cull and unpoll. fruit from Cal Date ^a 1966 crop	None	0	0	36	67	0	0	36
20 Oct. 1967	Fruit from bunch cut 10/06/67 Bunch was in shop for 2 weeks	None	30	87	30	100	0	0	60
23 Oct. 1967	Cull and unpoll. fruit from Cal Date, 1966 crop	31 ft/min	6	83	254	37	0	0	260
14 Nov. 1967	Fruit from aerial poll. bunches 4 days after harvest	35 ft/min	70	69	69	86	37	0	139
14 Nov. 1967	Hand pollinated, 4 days after harvest	35 ft/min	200	67	0	0	37	97	237

^a Cal Date = California Date Growers' Association

cpm or higher instead of in the originally intended range of 700-800 cpm. However, selectivity at a 3-inch stroke and 1180 cpm was within a few per cent of all points plotted in Fig. 1.

Table 1 is a summary of results for bunches that had a high per cent of unpollinated fruit. It appears that the 3-inch stroke at 700 cpm had an advantage over the 6-inch stroke because more fruit were removed without calyces. This is desirable because a number of packing-house and marketing problems are caused by the presence of the calyx.

FRUIT SEPARATION AFTER HARVEST

Evaluation of Separation Methods. Several methods of separating the unpollinated from pollinated dates were tried. The procedure outlined in Fig. 2 was used to evaluate the effectiveness of different separation methods. If hand sorting were the way to separate unpollinated from pollinated dates, then the amount of hand sorting required for any lot of unsorted fruit would be directly proportional to the per cent of unpollinated fruit in the lot. If, however, a mechanical separation method were available, but did not work perfectly, the amount of hand sorting required to completely separate the unpollinated from pollinated fruit would be directly proportional to the total hand removal (HR) necessary after mechanical separation. If HR for a given separation method was less than the per cent of unpollinated fruit in the unsorted fruit, that method would reduce the total number of fruit that must be hand sorted. The difference between sorting out all unpollinated fruit and sorting out pollinated or unpollinated fruit not correctly separated mechanically may vary with different lots of fruit and separation methods.

Fig. 3 shows the relationship between the difference (i.e., difference = (100 - Pp) - HR) in required sorting for any separation method and a given per cent of pollinated fruit in the unsorted lot. If the difference is a positive value, that particular separation method will eliminate some hand sorting. The line at the extreme right where Sp = 100, Sup = 100 represents a perfect separation method which will eliminate all hand sorting due to the presence of unpollinated fruit. The lines extended into the minus portion of the graph illustrate that at higher values of Pp (high lot pollination) any separation method will have to be highly effective to be of benefit. Any minus value indicates a separation method is ineffective and results in an increase rather than decrease in the amount of hand sorting.

For a mechanical separation method to be of much benefit on lots of fruit such as those previously cited for the 1966 aircraft pollination plots (a maximum of 18% unpollinated fruit, i.e., Pp = 82, at one plot even though yield was equal to hand pollination), Sp and Sup would both have to be in the order of 90% or greater.

Water Separation. The floating characteristics of both types of fruit were observed to determine if immersion in still or moving water could be used to separate the unpollinated from the pollinated fruit. For the still water test, fruit were placed in a small container of water and classified as having either sunk or floated. Some fruit had a specific gravity near 1.0 and seemed suspended just below the surface; these were classified

as sinkers. The moving water test was conducted in a small flume shown schematically in Fig. 4.

Results: A small sample of fruit obtained from an aerial-pollinated bunch early in the harvest season (Oct. 6) showed the most consistent separation in still water: 80% of the pollinated fruit sank and 100% of the unpollinated fruit floated (Table 2). Two weeks later, fruit from the same bunch gave similar results, with 87% of the pollinated fruit sinking and again 100% of the unpollinated fruit floating.

Fruits from a bunch which matured later in the harvest season (Nov. 10) were less consistent. Four days after harvest a still-water test resulted in 69% of the pollinated fruit sinking and 86% of the unpollinated fruit floating. These figures suggest that the specific gravity of the fruit changed as the harvest season progressed. The pollinated fruit progressively lost some weight while its volume remained essentially the same. The unpollinated fruit decreased in volume while its weight remained nearly constant. Therefore, as the harvest season progressed, less pollinated fruit would sink and less unpollinated fruit would float; thus, the water separation method became less effective. Pollinated fruit from hand-pollinated bunches had floating characteristics similar to pollinated fruit from aerial-pollinated bunches harvested at the same time. In a test of unpollinated fruit from the 1966 harvest season which had been in outdoor storage for nearly a year, from 67% (still water) to 37% (moving water) floated.

Referring to Fig. 3, and using 2 water separation values, which represent as high a degree of separation as can be expected throughout a harvest season, of Sp = 80 (80% of the pollinated fruit sank), Sup = 100 (100% of the unpollinated fruit floated), and Pp = 90, there is an 8% increase in the number of fruit that must be hand sorted. However, if a lot had only 50% pollination, the number of fruit hand sorted would be reduced 28%.

It appears that the best time for water separation in either moving or still water is early in the harvest season and within a few days after actual harvest. Fruit must now be fumigated, for about 10 days, immediately after being delivered to the receiving station and then most

fruit is stored in the fumigation blocks for several months before being sorted. Fruit that is wet or has a high moisture content cannot be stored without moulding; therefore, water separation has some practical limitations.

Size Separation. Often, unpollinated and pollinated fruit in an aerial-pollinated garden are about the same size early in the harvest season. The size difference increases later in the harvest season as the unpollinated fruit begins to dry. Unpollinated fruit rapidly decrease in size during outdoor storage. Fig. 5 shows the change in size of fruit in the same lot after one month of storage. The diameter was an average, measured with a calipers at what appeared to be the largest cross-section of the fruit. At the first measurement, 95% of the unpollinated fruit had a diameter of 0.75 inch or less. One month later, 98% had a diameter of 0.60 inch or less, a substantial decrease in the diameter and therefore volume, of unpollinated fruit. Also, at the time of the second measurement, 1% of the pollinated and 99% of the unpollinated fruit had a diameter of 0.65 inch or less. If a sizer were set to pass all fruit of 0.65 inch diameter and less, the separation would theoretically have been near perfect, or would be at Sp = Sup = 99 in Fig. 3.

A diverging roller sizing unit was built to test the effectiveness of diameter sizing as a method of separating unpollinated from pollinated fruit. The combination of a rotating rubber-covered roller and a stationary steel roller, both 1½-inches diam, was satisfactory for sizing. A slope of 13-20° to the horizontal gave adequate translation of the fruit down the sizing unit.

Results: The per cent of pollinated or unpollinated fruit which passed between the rollers and into one of the size classifications is shown in Table 3. The fruit used in the first 7 runs had been harvested in early January and then stored outside for 2 weeks. In the first 4 tests, Sp ranged from 90-96 and Sup ranged from 69-92. Assuming the highest values of Sp = 96 and Sup = 92 in a lot of fruit with Pp = 82, Fig. 3 would show a reduction in hand sorting of 13.3%. A lot of fruit with Pp = 90 would result in a reduction in hand sorting of only 4.4%. In tests 5 thru 7, Sp = 100 and Sup ranged from 25-45. Again, the highest

TABLE 3. Results of separating date fruits by diameters with a diverging roller sizing unit

Test	Test Conditions			Sample		Opening ^b		Size I, larger than opening		Size II, smaller than opening	
	Time after harvest	Roller speed	Total fruit	Poll. ^a fruit	between rollers	Poll. fruit Sp	Unpoll. fruit	Poll. fruit	Unpoll. fruit	Poll. fruit	Unpoll. fruit Sup
no.	weeks	rpm	no.	inches	%	%	%	%	%	%	%
1	2	700	200	50	0.87	90	12	10	88		
2	2	1200	100	50	0.87	94	8	6	92		
3	2	1200	100	50	0.87	96	22	4	78		
4	2	700	297	51	0.87	93	31	7	69		
5	2	1200	428	26	0.64	100	74	0	26		
6	2	1200	483	26	0.64	100	55	0	45		
7	2	1200	702	45	0.64	100	75	0	25		
8	6	850	533	28	0.66	99	39	1	61		
9	6	850	176	77	0.66	99	41	1	59		

^a Abbreviations: poll. = pollinated; unpoll. = unpollinated.

^b Opening = open space between the diverging rollers at the division point between Size I and Size II.

values of $S_p = 100$ and $S_{up} = 45$ in a lot of fruit with $P_p = 82$ would result in a reduction in hand sorting of 8.1%, whereas a lot of fruit with $P_p = 90$ would result in a reduction of only 4.5%.

The last 2 tests were conducted after the fruit had been stored outside for 6 weeks. The per cent of unpollinated fruit in Size II increased; however, 1% of the pollinated fruit was also present. Decreasing the opening between rollers could eliminate the pollinated fruit in Size II but would probably have a greater undesirable effect on the per cent of unpollinated fruit in both Size I and Size II. Assumed values of $S_p = 99$, $S_{up} = 60$ in lots of fruit with $P_p = 82$ and 90 would result in a reduction of hand sorting of 10% and 5.1%, respectively.

Roller rpm, within the 700-1200 range, did not appear to substantially influence the results. The increasing difference in diameter between pollinated and unpollinated fruit, which normally occurs during storage and with advancing harvest season, will result in a correspondingly higher degree of separation. Also, the relation of fruit size, space between rollers, and location of the dividing barrier between groups are factors that determine the optimum benefit which can be obtained.

Other Methods Considered. If the properties of the 2 types of fruit were always different from each other and distinct enough, they might move in different directions on a vibrating table and consequently be separated. However, the anticipated capacity of such a separator would probably be low because the amount of fruit moving over the vibrating table would have to be small to minimize contact between pollinated and unpollinated fruit.

Early in the harvest season, the unpollinated fruit tend to be smooth and cylindrical, whereas pollinated fruit are more irregular. Hence, to begin rolling on an inclined surface the pollinated fruit would require a greater angle from the horizontal than unpollinated fruit. Such a system would require singularization of fruit and its potential capacity is low. Again the physical changes in both types of fruit during the harvest and storage season would greatly affect the results.

Some optical instruments which measure the light transmitted through biological products may be able to differentiate between the two types of fruit. The presence of a pit in a pollinated fruit would probably make it more opaque than an unpollinated fruit. This type of system might possibly be justified if this same principle could aid in further grading by also sorting pollinated fruit according to moisture content.

Color sorting by reflected light is a possibility early in the harvest season; however, late in the harvest season the color of the 2 types of fruit is nearly the same. One manufacturer of reflected-light sorting equipment was able to distinguish between the 2 types of fruit early in the season.

CONCLUSIONS

1. Attempts to shake date bunches and selectively remove pollinated fruit while leaving unpollinated fruit on the bunch revealed that the ratio of the 2 types of

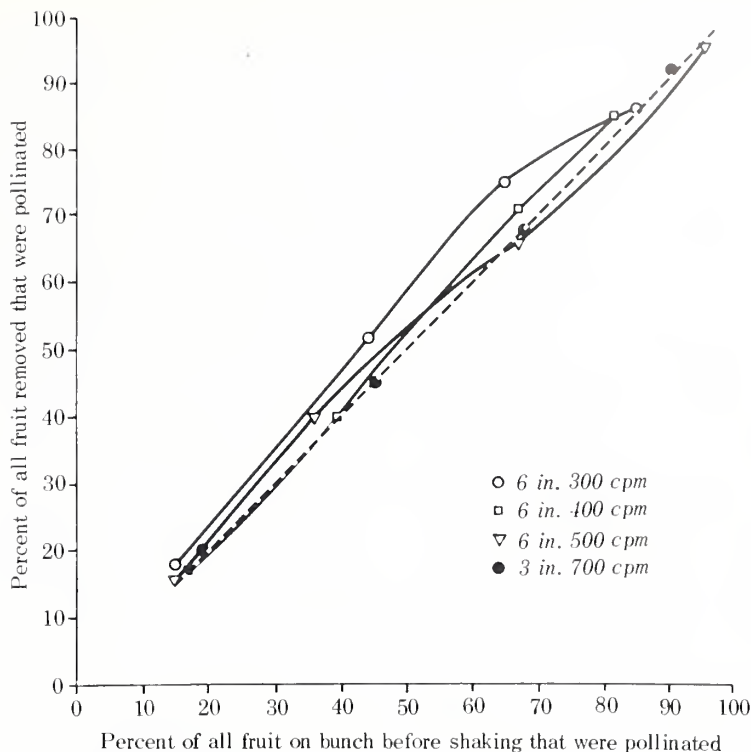


FIG. 1. Results of selective fruit removal by shaking at various strokes and frequencies.

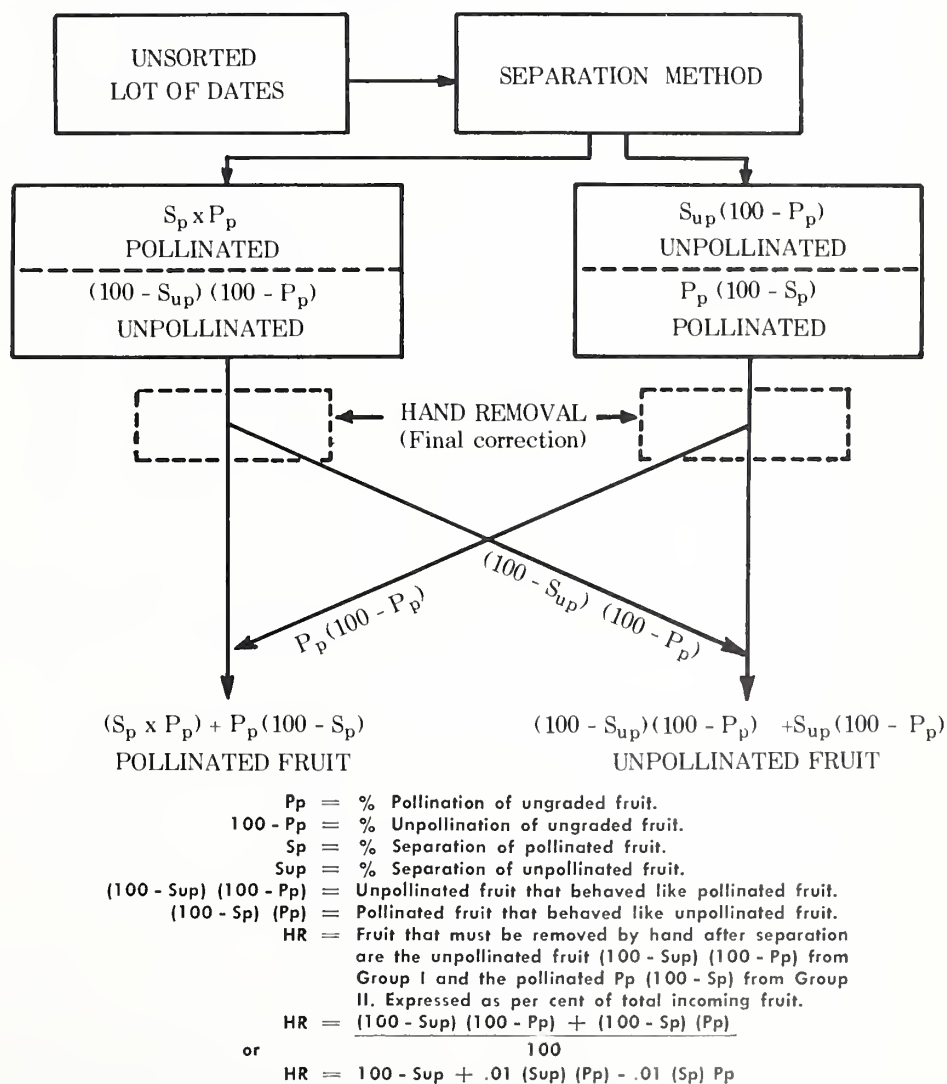


FIG. 2. Diagram and nomenclature of a 2-way separation method.

fruit removed was nearly in direct proportion to the per cent bunch pollination; hence, no selectivity.

2. Water-separation methods yielded best results on fruit harvested early before the unpollinated fruit began to dry. However, the field-run fruit must now be held in fumigation blocks for a minimum of 10 days before being sorted. Use of a water-separation method before fumigation seems impractical since wet fruit cannot be stored without spoilage.

3. Sizing of field-run fruit by diameters may reduce the total number of fruit that must be removed by hand if the sizing operation is closely supervised. The sizer would have to be set according to the size distributions of the pollinated and unpollinated fruit in each lot.

4. In general, the physical characteristics of the unpollinated fruit change appreciably during the harvest season. A method that does a good job of separating fruit early in the harvest season may be much less effective later or after the fruit has been in storage. If each lot of field-run fruit contained 90% or more of pollinated fruit, a mechanical separation method would need to be very effective to be of much benefit. But, if many lots of fruit contained 60% or less of pollinated fruit, a less effective mechanical separator could substantially reduce the amount of hand sorting required to separate the pollinated and unpollinated fruit.

5. Separation of unpollinated from pollinated fruit by sizing appears to offer the simplest and most readily available method of mechanical separation should the problem of unpollinated fruit occur again as it did in 1967 aircraft pollination tests.

LITERATURE CITED

1. Brown, G. K., R. M. Perkins, and E. G. Vis. 1969. Developing ground level equipment for pollinating dates. Date Growers' Inst. Rep. 46; , 1969.
2. _____, and _____. 1969. Experiments with aircraft methods for pollinating dates. Date Growers' Inst. Rep., 46:
3. Nixon, R. W. 1966. Growing dates in the United States. U. S. Dep. Agr. Info. Bull. 207, 56 p.

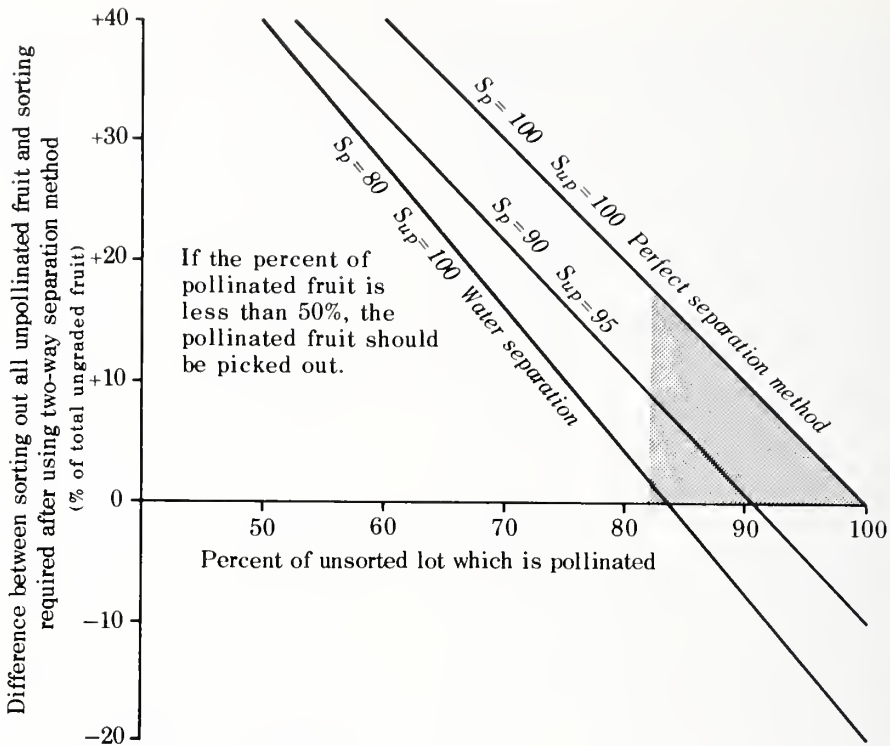


FIG. 3. The effect of separation methods on the amount of hand sorting required to complete separation.

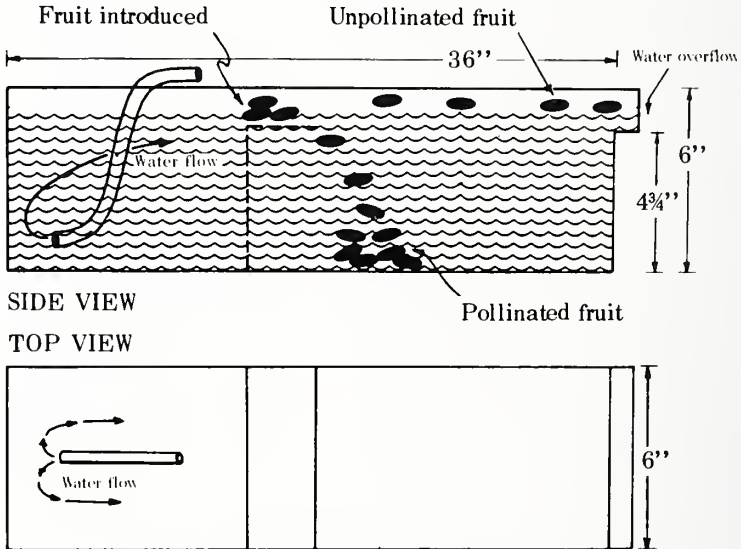


FIG. 4. Plexiglas flume used for water separation of dates.

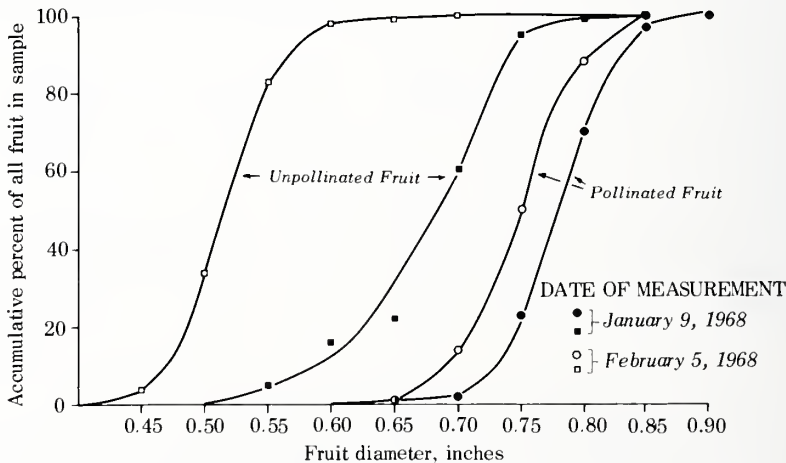


FIG. 5. The change of the diameters of pollinated and unpollinated dates in storage.

AN IMPROVED PESTICIDE DUSTER FOR DATE PALMS

G. K. BROWN, R. M. PERKINS, AND E. G. VIS¹

The harvesting of California dates has been mechanized by delaying harvest, cutting whole, highly mature bunches from the palm and shaking off the fruit with mechanical shakers (1, 7). Dates that are not picked as they become ripe dehydrate and then are quite susceptible to insect infestation (5).

The major portion of producing date acreage in the Coachella Valley of California was planted before 1940. These palms are now producing fruit at heights of 40 to 60 ft. Adequate control of mites or insects, both early and late in the crop year, requires that the acaricide or insecticide be thoroughly applied to the entire bunch. Vincent and Lindgren (8) have shown that the best mite control (Banks grass mite) was obtained by blowing sulfur dust directly upward into the bunches. Observations by Elmer (3) revealed that poor control of mites with sulfur dust was often correlated with inadequate coverage.

An application of 25 to 50 lb. per acre of 98% dusting sulfur, the only acaricide registered for use on dates, is recommended for mite control (5). An application of 50 to 80 lb. per acre of 5% malathion, the only insecticide registered for use on dates, is recommended for the control of most insects (4, 6). Some growers have increased use of both materials to nearly 100 lb. per acre per application, but mite and insect damage continues to be a problem.

The project discussed in this report was initiated in May 1968 to develop an improved method of pesticide application for commercial field conditions. It is a part of the production mechanization project initiated in 1966 by the U. S. Department of Agriculture with the cooperation of the California Agricultural Experiment Station.

The objectives of this research are to develop an improved pesticide application system which: 1) will control infestation; 2) will thoroughly cover both open and bagged bunches regardless of palm height, variation in palm height in a garden, and wind conditions; 3) will have a work rate in acres per hour equal to or greater than present equipment; 4) will not require more than the present recommended amount of dusting material.

PROCEDURE

To meet these objectives a trailer-mounted palm duster (Figs. 1, 2), similar to the one used for pollination experiments in 1968 (2) was constructed. This dusting system required one tractor driver and one duster operator. The operator directed a pesticide delivery pipe at the bunches from an adjustable platform which was 9 ft. above ground at its lowest point and could be raised to 24 ft. above the ground. The delivery pipe was counterbalanced and gimbal-mounted

from the platform in front of the operator. The delivery pipe within reach of the operator was 3-inch PVC plastic, for electrical safety, and the upper portion beyond reach of the operator was 2-inch aluminum irrigation pipe topped by a 1-inch diameter nozzle, for light weight and rigidity. Three different lengths of aluminum pipe were interchangeable for dusting in gardens with predominantly short, medium, or tall palms. A "Roots"² type blower provided about 125 ft.³/min of air to convey the pesticide at about 250 mph as it left the nozzle.

Since dusting materials cannot be conveyed through this type of blower, it was necessary to meter pesticide into the pressurized air stream from an airtight hopper. This was accomplished with a 1½ inch diam. earth auger, turning at about 36 rpm, located in a horizontal pipe at the bottom of the hopper.

This experimental duster began operation in mid-July in sulfur dusting and continued to be used by a cooperating grower for malathion-ferbam and malathion applications in 4 separate gardens until the end of the crop year. These gardens were fully mature (fruit bunches between 35 and 55 ft. above ground after tiedown) and amounted to 150 acres. They are separated by 3 to 10 miles and may be considered representative of a major portion of the date growing area of the Coachella Valley.

Dust penetration of the bunches and deposit on the fruit by this duster and conventional dusters were observed. Records of mite and insect damage in each truck load of fruit delivered to the packinghouse were made available by the grower.

RESULTS

Control. Table 1 summarizes the 1967 and 1968 records for the 4 gardens in-

cluded in this experiment. The experimental duster was used only for the last sulfur application on the 1968 crop, so the data given for mite damage are for a combination of conventional and experimental methods. The average infestation was 0.6% and the average mite damage 0.0% for the 2,000,000 lb. of dates dusted with the experimental duster. There was a substantial reduction of infestation in all 4 gardens in 1968 compared with 1967. Some of this difference may be due to a difference in the mite and insect population caused by climatic conditions, but some growers experienced high mite damage and insect infestation in the 1968 crop.

Coverage. The duster nozzle was maintained about 6 ft. below the bunch when dusting bagged bunches. Coverage was good throughout the entire bunch because the dust penetrated the bunch and was deflected back down by the bag. The top of the fruits had the heaviest deposit because the dust settled on the fruit.

The conventional duster, as normally operated, tended to deposit most of the material on the bottom of the bunch and the bottom of the fruits; often the center and top of the bunch had little or no pesticide deposit. Bags which were larger than the bunch tended to open as the air-stream hit the bunch and to allow pesticide to settle on the top of the bunch, but penetration of the bunch was still poor. These results indicate that the centrifugal dusters used by most growers cannot blow dust to the tall palms with enough velocity to thoroughly penetrate the bagged bunch of tightly packed dates.

The experimental duster was often used during wind conditions which would have resulted in unfavorable results with a conventional duster. Control of the dust stream, penetration of bagged bunches, and pesticide deposit on the fruit were satisfactory because of the high velocity of the dust as it left the nozzle and the

TABLE 1. Summary of insect infestation and mite damage—packinghouse records for total crop

Crop year	Garden	Annual avg insect infestation	Percent of loads received at indicated infestation level and less												
			No.	%	0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
1967	1	3.2	7.5	26.9	43.3	59.7	76.1	85.0	92.5	95.5	97.0	98.5	100.0		
1967	2	2.8	2.3	16.3	46.5	67.4	88.3	100.0							
1967	3	5.1	2.2	6.6	24.4	28.8	46.6	51.0	59.9	77.7	91.1	100.0			
1967	4	3.0	5.8	21.2	46.2	69.3	80.8	88.5	94.3	96.2	100.0				
1968	1	0.8	36.8	89.4	94.7	100.0									
1968	2	0.8	40.3	87.1	95.2	98.4	100.0								
1968	3	0.3	73.8	97.6	100.0										
1968	4	0.5	53.7	94.4	100.0										

Crop year	Garden	Annual avg mite damage	Percent of loads received at indicated mite damage level and less												
			No.	%	0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
1967	1	2.0	73.1	73.1	77.5	77.5	80.5	88.0	91.0	91.0	92.5	94.0	95.5	100.0	
1967	2	0.0	100.0 ^a												
1967	3	0.3	93.4	93.4	93.4	95.6	97.8	97.8	100.0						
1967	4	0.0	100.0 ^a												
1968	1-4	0.0	100.0 ^a												

^a If most lots have mite damage, it is shown separately on receiving tickets. If mite damage is only occasional, damage of 1-5% will be entered with other damage as miscellaneous. Only lots with over 5% mite damage will show it separately.

¹ G. K. Brown and E. G. Vis are Agricultural Engineers, Harvesting and Farm Processing Research Branch, Agricultural Engineering Research Division, ARS, USDA, Riverside, California. R. M. Perkins is Associate Specialist, Agricultural Engineering Department, University of California, Riverside, California.

ability to control the distance between the nozzle and the bunches.

Work Rates. When sulfuring unbagged bunches, making one pass on each row side of the palm, the experimental duster could move at 2 to 3 mph, depending on the ground conditions and variation of palm height, which was a dusting rate of $3\frac{1}{2}$ to 5 acres per hr. When applying malathion mixtures to bagged bunches, the operator had to make one pass on each row side of the palm at 1 to $1\frac{1}{2}$ mph to allow time to direct dust into each bunch. This was a rate of $1\frac{3}{4}$ to $2\frac{1}{2}$ acres per hr.

These work rates are similar to or somewhat better than those for the growers' conventional duster under the same garden conditions.

Amount of Pesticide Required. The pesticide metering rate, (auger rpm) was selected so that about 50 lb. per acre of 5% malathion dust would be applied at a ground speed of $1\frac{1}{2}$ mph, and about 25 pounds per acre of 98% dusting sulfur would be applied at a ground speed of 2 mph. The grower reported that about 40% less pesticide was applied per application with the experimental duster than with his conventional duster.

Other Considerations. Observations of dusting operations suggested that bagging and tiedown could be changed to improve mite and insect control as well as speed up the dusting operation. Most papers used for bagging maturing bunches are square and have one corner hanging down when placed over the bunch (Fig. 1). In many cases, these corners tended to close the bottom of the bag and prevent dust from entering. If a 3-cornered paper were used, the dust coverage on many bunches would be improved and the duster could move faster and therefore cover more acres per hr. Unevenly tied bunches also made it difficult to achieve uniform pesticide coverage. Sometimes, small or late bunches were tied higher than large or early bunches, or many bunches were tied in a group rather than separately around the palm. All of these conditions tended to reduce or completely block the entry of pesticide into the bunch. Care should be taken to locate bunches as evenly as possible around the palm during tiedown to expose each bunch for adequate pesticide application.

DISCUSSION AND CONCLUSIONS

The results from the first year of developmental work indicate that the requirements established at the start of this project have been met. While the results of one year's work are not adequate to make final recommendations, the results do suggest that the dusting system discussed in this report will perform better in tall palms than conventional centrifugal dusters. Three additional dusters of this type are being built by interested growers for use on the 1969 crop. Trials with the duster discussed in this report will be repeated on the same acreage during 1969 to gain additional data and experience.

Consideration should be given to using 3-cornered or shaped bagging papers instead of square papers to improve dust coverage and speed up the dusting operation. More care in the uniform spacing of bagged bunches around the palm will insure adequate dust application.

The duster has been developed so that a slight modification will allow it to be



FIG. 1. Elevating palm duster applying malathion to tall palms with bagged bunches.

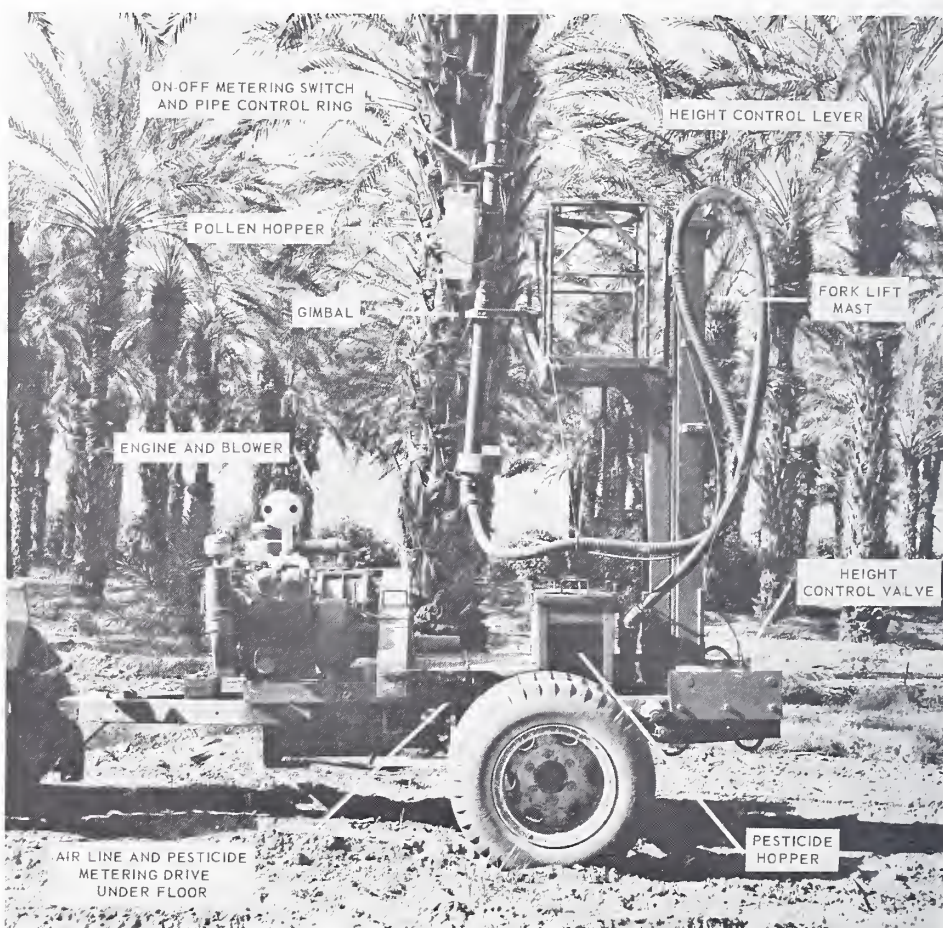


FIG. 2. Elevating palm duster showing physical arrangement of equipment.

used for pollination. If the pollination research is successful, this duster will have multiple use and in a short time will effect savings adequate to offset the equipment cost to most growers.

LITERATURE CITED

1. Brown, G. K., and R. M. Perkins. 1967. Harvesting dates mechanically. Trans. Amer. Soc. Agr. Eng. 10:486-488.
2. _____, and E. G. Vis. 1969. Developing ground level equipment for pollinating dates. Date Growers' Inst. Rep. 46:_____.
3. Elmer, H. S. 1961. 1960 results using new insecticides and methods for the control of date insects and mites. Date Growers' Inst. Rep. 38:17-18.
4. _____. 1966. Date palm insect and mite pests in the United States. Date Growers' Inst. Rep. 43:9-14.
5. _____. 1967. Malathion, a factor in date harvesting. Date Growers' Inst. Rep. 44:7-8.
6. _____. 1968. Evaluation of the effects of malathion dust applications for the control of date-infesting insects. Date Growers' Inst. Rep. 45:12, 13.
7. Perkins, R. M., and G. K. Brown. 1964. Progress in mechanization of date harvesting. Date Growers' Inst. Rep. 41:19-23.
8. Vincent, L. E., and D. L. Lindgren. 1958. Control of the date mite *Oligonychus pratensis* Banks in California. Date Growers' Inst. Rep. 35:15-17.

TEMPERATURE AND HEAT UNIT OCCURRENCES DURING DATE POLLINATION IN THE COACHELLA VALLEY OF CALIFORNIA

G. K. BROWN, R. M. PERKINS, AND E. G. VIS¹

The temperature and heat unit studies discussed in this report were conducted as a part of the date pollination project initiated in 1966 by the U. S. Department of Agriculture with the cooperation of the California Agricultural Experiment Station. These studies are concerned only with the temperatures which occur from March 1 through May 14, the period during which the date variety Deglet Noor is pollinated. Hand pollination of this variety normally starts in most areas of the valley about March 10. The supply of labor for hand pollination is decreasing (2); so some method of pollination is needed which will result in satisfactory yield with reduced labor requirements.

Experiments using helicopter and fixed-wing aircraft for pollen application were conducted in the spring of 1966 and 1967 (1). Pollination experiments using ground-level equipment were initiated in the spring of 1968 (2). In 1966, the helicopter method, using 2 combinations of application rate and frequency, yielded as much pollinated fruit as hand pollination, or more, but in 1967 the same method yielded considerably less than hand pollination. The differences between years appeared to be due to lower temperatures during pollination in 1967 than in 1966. Reuther and Crawford (6) reported that low temperatures during pollination in 1935 and 1945 resulted in widespread poor set of Deglet Noor and other varieties in the Coachella Valley. If temperatures during the pollination period can greatly influence fruit set, the risk of adverse temperature occurrence should be defined.

Furr and Ream (4) showed that date pollen in culture solution did not germinate at 45°F, but that germination began and increased with rising temperatures from 45° to 90° F. At 110°F germination was seriously impaired by the direct effect of high temperature. Their tests were conducted at constant temperature levels for periods from 10 min to 48 hr. The effect of diurnal temperature fluctuation on pollen germination is not known.

According to Swingle (7), DeCandolle calculated that growth of flower and fruit of the date palm ceases at temperatures of 18°C (64.4°F) and below. Swingle confirmed the correctness of this calculation by a study of data from a self-recording thermometer kept in a date garden at Biskra, Algeria. He discussed the 18°C temperature in relation to daily mean temperature rather than daily maximum temperature.

Reuther and Crawford (6) correlated set of hand-pollinated fruit at 4 locations in the Coachella Valley with the total heat (degree-hours of heat above 60°F) which was recorded at the U. S. Date

and Citrus Station, Indio (hereafter referred to as Indio or Indio Station), during the week following pollen application. Some date growers in the Coachella Valley have also used a degree-day heat unit summation (average daily temperature minus 50°F) to estimate the date of crop maturity (3). These so-called heat units are temperature-time summations rather than actual heat energy (BTU, cal, etc.). Heat cannot be directly used by any plant for growth but can control the rate at which chemical energy, present in stored food, is made available for growth. Many researchers have used heat unit summations, in one form or another, and found a good correlation with plant growth for certain temperature conditions. Their findings and several approaches to the heat unit concept are discussed by Went (9).

METHODS OF TEMPERATURE ANALYSIS

The stigma of the date flower is slender and protrudes about 1/2 mm above the surface of the flower. Consequently, the temperature of the stigmatic surface on which pollen germinates is probably equal to the surrounding air temperature. A previous study (4) showed that both adequate temperature and time are required to reach a maximum level of pollen germination. However, if too long a time is required for germination, the stigma may dry and become non-receptive.

The pollen germination rate can be closely predicted from the daily maximum temperature. The daily average temperature is not adequate for such predictions because the same average can be obtained from many minimum and

TABLE 1. Deviation^a of maximum temperatures of USWB Spring Stations and Project Garden Stations from U. S. Date and Citrus Station at Indio during the period March 1 - May 14, 1968

Station No.	Average deviation ± °F	Maximum daily deviation ± °F	Station No.	Average deviation ± °F	Maximum daily deviation ± °F
105	0	+4 -5	117	0	+5 -4
106	-1	+2 -6	118	0	+5 -5
107	-1	+4 -8	119	0	+2 -6
108	-2	+3 -5	120	-1	+2 -6
109	+1	+5 -2	121	0	+4 -5
101	-1	+2 -5	122	0	+5 -4
103	-2	+4 -6	123	-1	+2 -7
104	+1	+5 -3	124	+1	+4 -5
110	-2	+2 -6	125	-2	+2 -6
112	-1	+2 -6	13	0	+4 -13
113	0	+3 -5	15	-3	+7 -7
114	0	+3 -4	17	0	+2 -6
115	-1	+2 -5	20	0	+2 -5
116	0	+3 -4	22	+1	+6 -4
126	-2	+2 -6	24	-1	+3 -6
127	-2	+1 -6	25	-2	+4 -8
128	0	+5 -3	29	-1	+3 -5
131	-2	+1 -4	34	-1	+3 -5
129	+3	+8 -2	36	-1	+3 -4
130	-3	0 -6			

^a All deviations were rounded to the nearest degree since the thermograph measurements were accurate to ± 1°F.

TABLE 2. Deviation^a of maximum temperatures of USWB Spring Stations from U. S. Date and Citrus Station at Indio during the period March 1 - May 14 of years 1956-1968

Station number	Maximum seasonal deviation ± °F	Average seasonal deviation ± °F
13	-1	+2 -4
15	-2	+2 -5
17	-0	+3 -3
20	-1	0 -1
22	+1	+4 -3
24	-1	0 -3
25	-1	+1 -3
29	0	+1 -2
34	0	+1 -2
36	0	+1 -2

^a All deviations were rounded to the nearest degree since the thermograph measurements were accurate to ± 1°F.

¹ G. K. Brown and E. G. Vis are Agricultural Engineers, Harvesting and Farm Processing Research Branch, Agricultural Engineering Research Division, ARS, USDA, Riverside, California. R. M. Perkins is Associate Specialist, Agricultural Engineering Department, University of California, Riverside, California.

maximum temperature values. Therefore, the method of temperature analysis used in this report involves only maximum temperatures.

Temperature records, on punched IBM cards, for March 1 through May 14 of years 1909 through 1968 for the Indio Station were obtained through the National Weather Records Center, Asheville, North Carolina. A program was prepared for an IBM 360 50 computer which would cumulate the daily maximum temperature and the number of times each temperature occurred for each day of all years. Each of these cumulations was then divided by 61 (the total number of years in the sample plus one) to yield the probability of occurrence of each maximum temperature. This procedure is similar to one described by Greene (5) in a study of temperature occurrence in Arizona and New Mexico.

To describe differences between years in terms of heat units, we made a summation of maximum degree-days (daily maximum temperature minus 60°F) for all years as well as for the periods March 1-30, March 31-April 29, and April 30-May 14. We used this summation, which is similar to the total degree-day summations, because hourly summations for so many observations would have required excessive hand calculation.

An analysis of temperature and heat values for other locations in the Coachella Valley was made for a shorter time. The U. S. Weather Bureau² furnished temperature records from their 11 spring temperature stations in the Coachella Valley, which have been maintained since 1956 during the months of March, April and May. In addition, 29 other stations were installed and maintained by the authors in the spring of 1968. These stations used Standard Weather Bureau type thermograph shelters located in date gardens which had been pollinated by aircraft in either 1966 or 1967. The locations of these stations are designated in Fig. 1. The 11 stations with numbers under 50 are U. S. Weather Bureau spring stations. Stations numbered 101 and greater were established in 1968.

RESULTS AND DISCUSSION

Daily Maximum Temperature. The analysis of maximum temperature occurrences for 1909-1968 (Fig. 2) indicates that maximum temperatures exceed 60°F on nearly every day between March 1 and May 14. After March 5 a maximum temperature of at least 70°F has a probability of occurrence higher than 80%. After March 26 a maximum temperature of at least 75°F has a probability of occurrence higher than 80%. It is not until after April 21 that a maximum temperature of at least 80°F has a probability of occurrence higher than 80%. Between March 24 and April 20 a strong warming trend occurs since the temperature occurring at the 50% probability level increases more rapidly than during either the prior or following time periods. In 1967, however, the period from March 24 through May 1 (38 days) had

consistently low temperatures. From 70 to 90% of the daily maximum temperatures recorded in other years were higher than those observed in this period of 1967. The lowest maximum recorded on March 29, 31, and April 19 (Fig. 2) occurred in 1967.

Temperature values for other locations in the valley are shown in Table 1. In 1968 only 5 of the 39 stations had an average daily maximum temperature higher than Indio and only 2 stations were more than 2°F lower than Indio. The results for individual days show maximum deviations of +8°F at one station and -13°F at another. This indicates that most locations will average slightly lower temperatures than Indio. The daily deviation is not consistent, probably due to a daily difference in wind conditions. Table 2 gives deviations from Indio for the spring stations during years 1956-1968. The 1968 deviations (Table 1) are within $\pm 1^\circ\text{F}$ of the 1956-1968 average deviation for each spring station (Table 2). The maximum seasonal deviations for each station indicate the year-to-year variation which can occur.

Maximum Heat Units. Heat summations, in terms of maximum degree-days, during the period of pollination for each year 1909-1968 are shown in Fig. 3. Heat

summations for 3 time periods during the pollination season are also shown. The reason that the latest period (April 30-May 14) has less heat units is that this summation covers only 15 days. Probability of occurrence curves, based on these long-term records, were calculated and are shown in Fig. 4. The heat summations vary considerably from year to year. The years 1935 and 1945, which Reuther and Crawford (6) reported had widespread poor set of fruit, were obviously 2 of the colder years. No reference was made to widespread poor set occurring in the years 1938, 1941, 1942, or 1944, which had heat summations similar to 1935 and 1945. It appears reasonable to conclude that unfavorable temperature periods of several days, at a time when most of the blooms should be pollinated, are probably responsible for poor fruit set. The results for years 1966 and 1967 show that 1966 was one of the warmer years (only about 15% were warmer), while 1967 was one of the coldest (about 95% were warmer); April 1967, the month of maximum bloom, was the coldest April on record.

Maximum degree-day summations for 7-day periods during the 1966 and 1967 pollinating seasons are shown in Fig. 5. The horizontal line at 100 degree-days

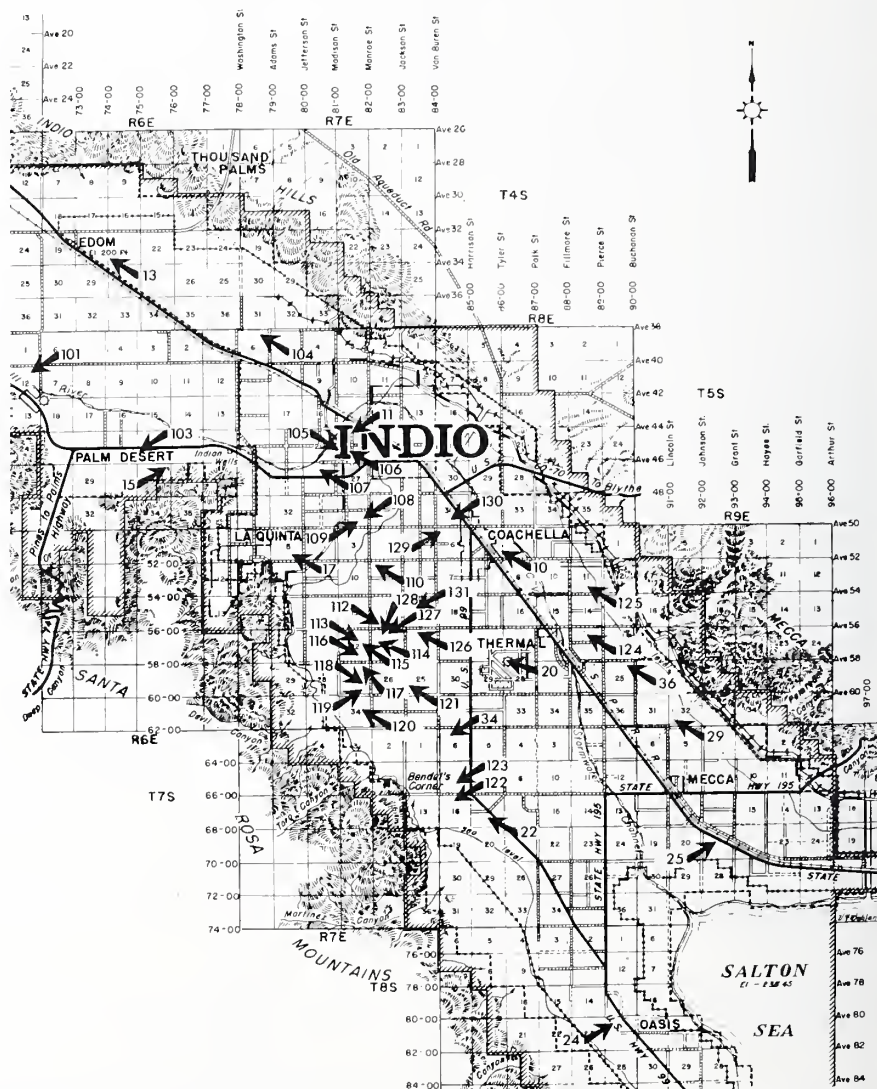


FIG. 1. Location of USWB Spring Stations and project garden stations in the Coachella Valley of California.

² The authors are indebted to Mr. Carl J. Garczynski, Meteorologist, U. S. Weather Bureau, Coachella, California, for his fine assistance in planning this temperature study, obtaining past records, and lending us most of the thermographs and shelters required for obtaining the 1968 records.

was determined as equivalent to the 700 degree-hour line, used by Reuther and Crawford (6), by plotting each type of data for the same period of time and matching the two resulting graphs. Heat values during the 1967 pollinating season were near the 100 degree-day, or 700 degree-hour, line from the last week of March to the last week of April. The 100 degree-day line represents an average daily maximum temperature of 74.3°F. Heat values during the 1966 season were not less than 165 degree-days during this same time period. Both the heat summation and maximum temperature analyses indicate that temperature could be a major reason for success in 1966 and failure in 1967 with aircraft pollination methods.

Maximum heat unit summations for Indio and 4 other stations, for the period March 1 through May 14 for the years 1956-1968, are shown in Fig. 6. These stations represent the warmest and coolest of the spring stations; so in nearly every year all other spring stations will have heat values between the warmest and coolest shown for any one year. Some variation in the order of stations, from warmest to coolest, will occur annually. The maximum difference observed among these 5 stations in any one year was 420 degree-days and the minimum difference observed was 80 degree-days. These represent differences in average maximum temperatures of 5.6°F and 1.1°F, respectively. Large or small differences between the warmest and coolest stations in any one year do not appear to be related to how relatively warm or cold the year was.

Use of Maximum Temperature and Heat Unit Results. The previous methods of analysis indicate that most locations examined in this report maintain average maximum temperature and heat conditions during pollination which are equal to or slightly cooler than Indio.

Maximum air temperature in the bloom area of palms at most locations in the valley will be lower than the air temperature in a standard U.S. Weather Bureau shelter located 4½ ft above ground level in the same date garden. Vis et al. (8) found that this difference could be as much as 7°F on separate days but probably would not be more than 4°F when averaged over 3 days or more. Palms near the Indio Station had bloom-area air temperatures about equal to shelter temperatures at that station.

The probabilities of maximum temperature and heat occurrences at Indio yield approximate probabilities of occurrences at other locations by appropriate use of deviations from Indio given in Tables 1 and 2, and any difference between ground level and bloom-area temperature. If a given location has a -2°F average deviation, the probability of 78°F occurring at that location is approximately the same as the probability of 80°F occurring at Indio; and the probability of 1350 maximum degree-days occurring at that location (for the 75 day period March 1-May 14) is approximately the same as the probability of 1500 maximum degree-days occurring at Indio. If the bloom-area of a date garden at that same location is another 2°F cooler than the weather station in the same garden, the probability of 76°F occurring in the bloom-area is approximately the same as the probability of 80°F occurring at Indio and the probability of 1200 degree-days occurring in the bloom-area is approximately the

same as the probability of 1500 degree-days occurring at Indio. The shape of the probability curves for each location will be slightly different than for Indio due to local differences in wind and surrounding conditions.

Temperature Conditions Resulting in Good Fruit Set. The effect of temperature, following hand pollination, on fruit set of Khadrawy dates on unbagged bunches was examined (6) at the Indio Station. The data indicate that 7-day maximum temperatures in the range of 75-80°F in the bloom area (assuming no

temperature difference between it and the Indio Station), resulted in 55-60% set; two days of about 85°F followed by an average maximum of 70°F resulted in 50% set; 70-75°F resulted in 35-45% set; and 65-70°F resulted in 23% set. One grower's records for 1967 showed that fruit set of unbagged Deglet Noor bunches was about 40% or less when Indio maximum temperatures for the week following pollen application were 69, 74, 76, 81, 78, 78, and 82°F. The bloom area temperatures in this garden were probably about 5°F cooler than the

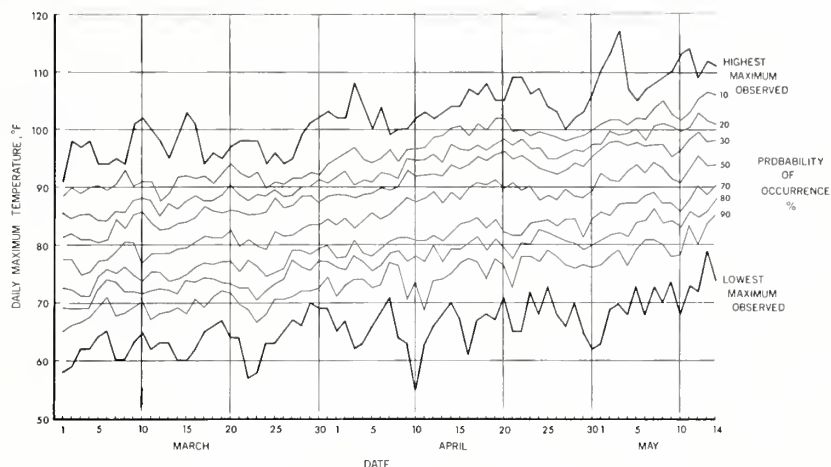


FIG. 2. Probability of occurrence of daily maximum temperatures, at least as high as indicated, at the U. S. Date and Citrus Station, Indio, California, during the period March 1 - May 14 based on data from years 1909 - 1968.

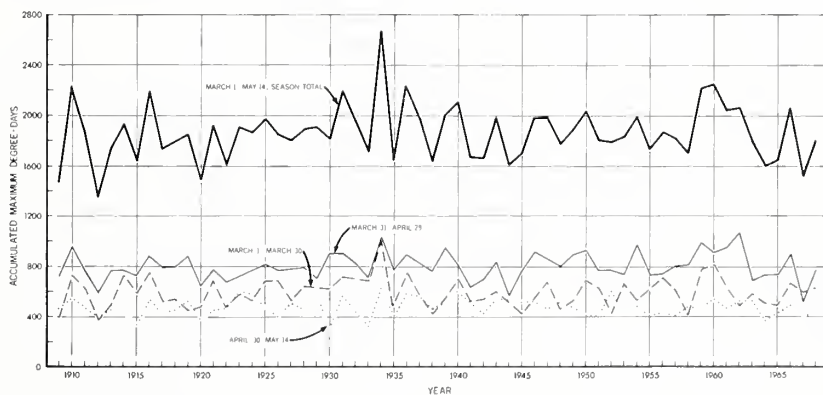


FIG. 3. Accumulated heat units at the U. S. Date and Citrus Station, Indio, California, in maximum degree-days (daily maximum temperature minus 60°F) for the indicated periods of years 1909 - 1968.

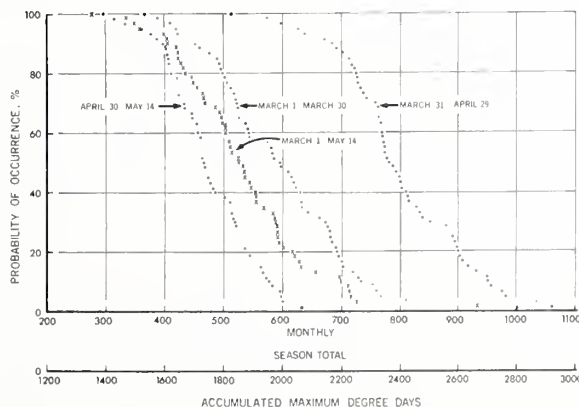


FIG. 4. Probability of occurrence of accumulated maximum degree-days (daily maximum temperature minus 60°F), at least as high as indicated, at the U. S. Date and Citrus Station, Indio, California, for the period March 1 - May 14 based on data from years 1909 - 1968.

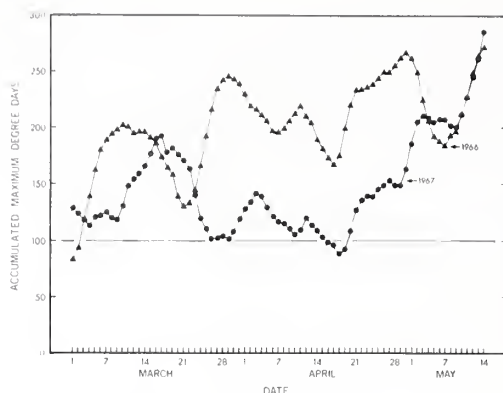


FIG. 5. Running accumulation of heat units, for 7 days following the date plotted, at the U. S. Date and Citrus Station, Indio, California, in maximum degree-days (daily maximum temperature minus 60°F).

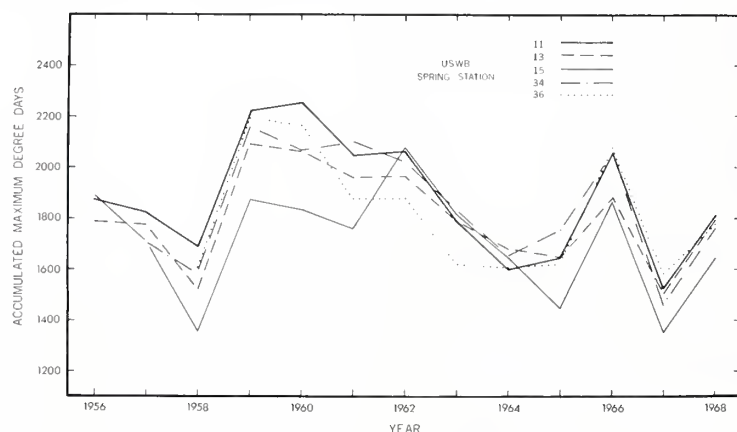


FIG. 6. Variation in accumulated maximum degree-days (daily maximum temperature minus 60°F) for five USWB Spring Stations, during the period March 1 - May 14 of years 1956 - 1968.

Indio readings; so most days would have been in the 70-75°F range. These results suggest that maximum temperatures of 75-80°F and higher must prevail in the bloom area to insure a fruit set of 55-60% and higher for hand-pollinated bunches which are not bagged. Mechanical pollination methods should give similar results if enough pollen is applied to the bloom.

Good fruit set depends upon favorable weather conditions for a few days after pollen application. The probability of good fruit set cannot be predicted with complete certainty from probabilities based on seasonal, monthly, or 7-day heat summations or even from daily maximum temperature probabilities because when unfavorable weather conditions occur, they usually last for 5-10 days and have lasted for nearly 40 days, as in 1967. An examination of temperature patterns for each of the last 60 years indicates that daily maximum temperatures under 75°F at Indio (with some days below 70°F) for periods of 5 to 10 days occurred nearly every year. Most of these were during early and mid-March but several occurred in late March and early April.

The information presented in this report suggests that if the bloom area of a date garden is as warm as Indio, either hand pollination without bags or mechanical pollination should result in good fruit set on most bunches pollinated after March 26 of each year since the probability of 75°F or higher occurring on each day after that date is better than 80%. Daily maximum temperatures from March 1 to 26 are likely to be erratic,

causing fruit set to vary from poor to good, since the probability of 75°F or higher occurring on each day varies from 50 to 80%. All locations in the valley usually have erratic daily maximum temperatures during March 1 to 26 because of storm conditions which affect the entire valley.

In addition to temperature and heat there are other factors such as wind and rain, which often accompany cool periods, as well as the nutritional level of the palms during the pollination season, which probably affect fruit set. These have not been considered in this report.

If more were known about the temperature-time-receptivity relationships resulting in good fruit set, a better estimate for success of mechanical pollination methods might be possible.

CONCLUSION

1. The study of daily maximum temperatures and maximum heat unit summation for several weather stations in the Coachella Valley indicates that most date-producing areas will be slightly cooler than Indio, some will be similar to Indio and only a few will be warmer than Indio.

2. Daily maximum temperatures at Indio exceed 60°F on nearly every day during the pollination period, March 1-May 14, of each year. An 80% probability of occurrence of a daily maximum temperature of at least 70°F on every day is reached after March 4, of at least 75°F on every day is reached after March 26, and of at least 80°F on every day is reached after April 21. The period from March 1-26 is likely to have erratic

weather with some daily maximum temperatures below 70°F.

3. Available records relating fruit set to daily maximum temperature indicate that good fruit set will occur on hand-pollinated blooms which are not bagged when daily maximum temperatures in the bloom area are in the range of 75-80°F or higher; marginal fruit set occurs when daily maximum temperatures are in the range of 70-75°F; and poor fruit set occurs when daily maximum temperatures are in the range of 65-70° or less.

4. Fruit set is likely to vary from poor to good until March 26 of each year unless hand pollination and bagging are used. After this date hand pollination without bagging or mechanical pollination methods should result in good fruit set. Yields should be satisfactory if adequate amounts of pollen are applied at proper intervals and thinning is adjusted according to fruit set. Some bunches having unpollinated fruit can be expected each year if these latter pollination methods are used.

5. Since many locations are cooler than Indio and in addition the bloom area of palms at most locations will be cooler than a ground-level weather station, temperature should be recorded at the bloom level if accurate records are desired.

6. Some practices which may improve the chances for success with mechanical pollination methods are: a) hand pollinate and bag until March 26; then if maximum temperatures are around 80°F in the bloom area, use mechanical pollination methods; h) use mechanical pollination methods in areas where palms bloom late; c) do not use mechanical pollination methods at locations where the bloom area daily maximum temperatures during pollination are frequently less than 75°F.

LITERATURE CITED

1. Brown, G. K. and R. M. Perkins. 1969. Experiments with aircraft methods for pollinating dates. Date Growers' Inst. Rep. 46:_____.
2. _____, and E. G. Vis. 1969. Developing ground-level equipment for pollinating dates. Date Growers' Inst. Rep. 46:_____.
3. Cook, R. E. 1956. Relationship of heat units to the ripening time of dates. Date Growers' Inst. Rep., 33:13.
4. Furr, J. R., and C. L. Ream. 1968. The influence of temperature on germination of date pollen. Date Growers' Inst. Rep., 45: 7-9.
5. Greene, Christine R. 1962. Probabilities of temperature occurrence in Arizona and New Mexico. Arizona Climate - Supplement No. 1, Inst. Atmospheric Physics, Univ. Ariz., Tucson.
6. Reuther, W. and C. L. Crawford. 1946. The effect of temperature and bagging on fruit set of dates. Date Growers' Inst. Rep., 23: 3-7.
7. Swingle, W. T. 1904. The date palm and its utilization in the Southwestern States. U. S. Dep. Agr. Bur. Plant Ind. Bull. 53.
8. Vis, E. G., G. K. Brown, and R. M. Perkins. 1969. The effect of elevation and time on air temperature during date pollination. Date Growers' Inst. Rep. 46:_____.
9. Went, F. W. 1957. The experimental control of plant growth. Chronica Botanica Co., Waltham, Mass. 343 p.

EFFECT OF ELEVATION AND TIME ON AIR TEMPERATURE DURING DATE POLLINATION

E. G. VIS, G. K. BROWN, AND R. M. PERKINS¹

The research discussed in this report was conducted as part of a study to define the temperature patterns which occur during the date pollination season in the Coachella Valley of California. Most of the available temperature data for the valley have been recorded by thermographs located in U. S. Weather Bureau shelters about 4½ ft. above ground level. To determine how accurately those data might represent temperature conditions affecting pollination, air temperature patterns from the 4½ ft. level to the bloom area of the palms (up to 50 ft. above ground in some date gardens) were studied at several locations.

Recent studies (2) indicate germination of date pollen is reduced by temperatures lower than 72°F. The fact that the date industry is interested in the development of a mechanized or semi-mechanized method of applying pollen makes an understanding of air temperature patterns quite important because such methods may place less pollen in the immediate area of the bloom than do the presently used hand pollination methods. Therefore, any climatological conditions adversely affecting pollination would be expected to have a greater effect on machine-pollinated bunches than on hand-pollinated bunches.

INSTRUMENTATION AND PROCEDURE

Air temperatures were measured with No. 24 copper-constantan thermocouples, painted white to reduce the effects of radiation, and were recorded by a multi-point temperature recorder equipped with an internal 32°F reference junction. The thermocouples were placed at several heights above ground level on the north and south sides of the palm about 8 inches out from the trunk. Thermocouples were also placed on the north and south sides of the bloom area, at the top of the palm, and in a thermograph shelter at the base of the palm.

Studies were conducted in 5 date gardens at locations given in Fig. 1. The average hourly temperatures were used for analysis at each garden. For the garden adjacent to the U. S. Date and Citrus Station, 4 temperatures at 15 min. intervals were used to calculate average hourly temperatures. The 4 remaining gardens had 2 to 8 readings per hr. from which to calculate an average hourly temperature.

RESULTS

Vertical Temperature Gradients: The average hourly temperatures at each height were subtracted from those at 4½ ft. above ground level. The differences for the hour from 2 PM to 3 PM, when the daily maximum temperature usually

occurred, are plotted in Fig. 1. The 2 outside lines indicate the range of extreme differences observed. The middle line is the average difference for all days on which temperatures were recorded. The average difference between the bloom area of the palm and the 4½ ft. level ranged from -0.33°F to -2.33°F. The extreme values show that for one day at Mitchell's Garden, air at the bloom level was 7°F cooler than at the 4½ ft. level. For the hour from 1 PM

to 2 PM (Fig. 2), the bloom area ranged from 0.33°F to 4.0°F cooler than the 4½ ft. level. These results indicate that air temperature in the bloom area of the palm was not more than 7°F cooler than air temperature near the ground during the 1 PM to 3 PM period and did not average more than 4°F cooler than air temperature near the ground when averaged over 3 days or more. Windy conditions tended to reduce this gradient especially if the gardens were

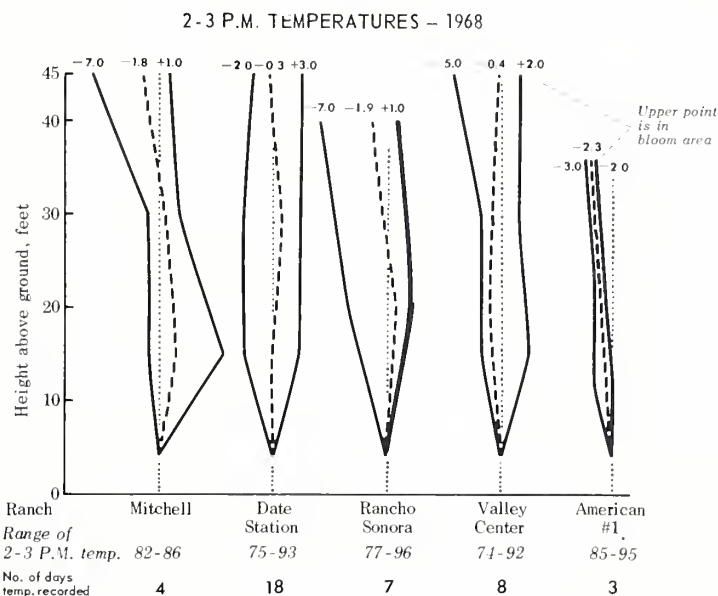


FIG. 1. Differences between temperatures at 4½ ft above ground and temperatures at elevations up to 45 ft during the 2-3 PM period. The negative differences indicate lower temperatures at the bloom area. Approximate ranch locations are: Mitchell, Calhoun and Ave. 50; Date Station, Clinton and Ave. 44; Rancho Sonora, Adams and Ave. 38; Valley Center, Harrison and Ave. 66; American Number 1, Monroe and Ave. 64.

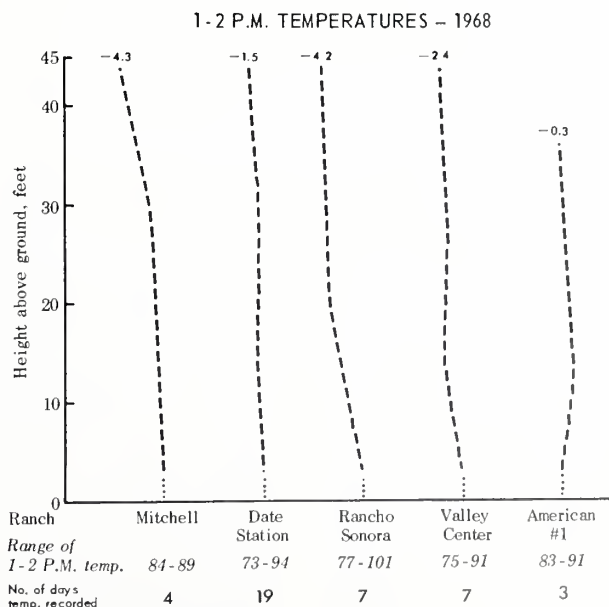


FIG. 2. Average temperature differences, as in Fig. 1, during the 1-2 PM period.

¹E. G. Vis and G. K. Brown are Agricultural Engineers, Harvesting and Farm Processing Research Branch, Agricultural Engineering Research Division, ARS, USDA, Riverside, California. R. M. Perkins is Associate Specialist, Agricultural Engineering Department, University of California, Riverside, California.

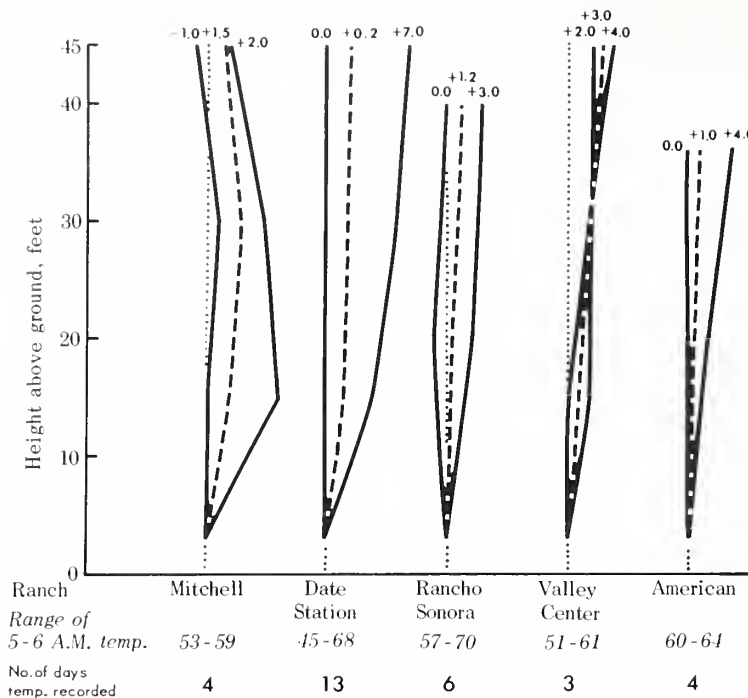


FIG. 3. Temperature differences, as in Fig. 1, during the 5-6 AM period.

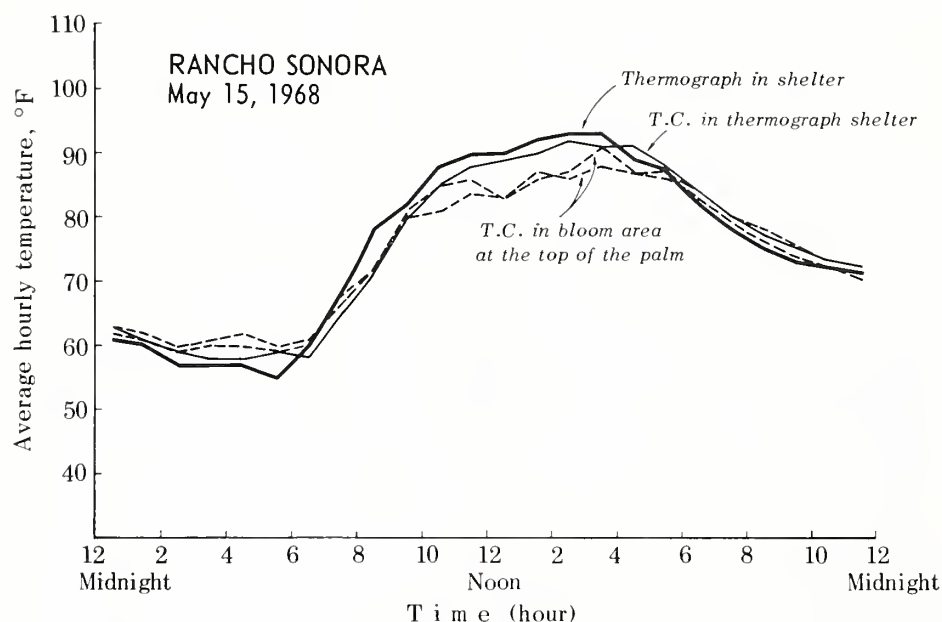


FIG. 4. Plot of average hourly temperature for one day as measured by a thermograph and thermocouples. (T.C.)

open and not bordered by windbreaks. With citrus interplanted in a date garden, air near the ground, in most cases, was warmer than at the top of the palm due to the restriction of air movement in the area of the citrus trees. Citrus trees tend to block some of the radiant heat given off by the ground, both day and night, and reduce the air temperature in the bloom area.

Similar observations of decreasing temperatures with increasing height during afternoons in the subtropical climate of Egypt have been reported by Geiger (3). A graph of daily air temperature at Riverside (4) illustrates comparable trends. Therefore, it seems reasonable to conclude that the vertical temperature gradient, with cooler air near the top of

the palm, can be expected in the date-growing area during the afternoon, when daily maximum temperatures occur.

The temperature gradient reversed early in the morning, and air at the top of a palm was warmer than air near the ground. Fig. 3 shows these gradients. The maximum average difference for the hour from 5 AM to 6 AM was +3°F, which occurred at the Valley Center Ranch.

Daily Temperature Patterns. The daily temperatures shown in Fig. 4 are representative of those which occurred on a calm day. The thermograph in the shelter recorded more extreme minimum and maximum temperatures than either the thermocouple in the shelter or the ther-

mocouples in the bloom area of the palm. These data further support some of the conclusions in the discussion of vertical temperature gradients. The temperature, as measured by thermocouples, was 1 to 2°F warmer at the top of the palm than at the shelter from 12 AM to 6 AM and 3 to 6°F cooler than at the shelter from 1 PM to 3 PM.

Temperature Differences When Measured by Thermographs and Thermocouples. Middleton (1) has stated that thermograph shelters without artificial ventilation can increase the recorded afternoon temperature by over 1°F. An official Weather Bureau thermograph at the U. S. Date and Citrus Station is located about 200 yards south of the palm where our thermograph and thermocouple equipment was located. The official thermograph shelter is not artificially ventilated and consistently recorded daily maximum temperatures about 5°F higher than our thermograph station, which also was not artificially ventilated. The official station is in a location that is exposed to the sun; in addition, in this location buildings, citrus trees, and shrubbery restrict the winds more than at our station located in the date garden. A similar situation was observed at the Mitchell Ranch where another official thermograph station averaged 9°F higher daily maximum temperatures than our station located in the garden. The official thermograph at this ranch is located close to a hedge, appears to lack good ventilation and is exposed to the sun in the afternoons. Bloom area air temperatures in the Mitchell Garden were as much as 15°F lower, and in the garden near the U. S. Date and Citrus Station were as much as 6°F lower than the temperatures recorded by each of the respective official thermograph stations. This demonstrates the error which may occur if temperatures are measured at some location other than the bloom area and if thermograph shelters are not adequately ventilated.

Hours Above a Base Temperature. The time interval necessary for fertilization of the date flower, following pollen application, at normal temperatures is not known, although the rate of germination of date pollen for different temperatures has been established (2). Fig. 5 shows the number of hours a day that were above a base of 70°F plotted against daily maximum temperature as recorded by the official thermograph at Mitchell's Ranch. The graph for March 7 - April 8, early in the pollination season, indicates that there were fewer hours above 70°F in this period than in the last part of April. The bloom area of the palms had fewer hours above 70°F than Fig. 5 indicates because the daily maximum temperatures were lower at that height. At the Indio Station (Fig. 6) there was a smaller difference in the number of hours above 70°F between the same 2 periods. These results indicate that the same daily maximum temperature can result in more hours above any given base temperature later in the pollination season than at the time pollination usually begins. Therefore, correlation of fruit set with daily maximum temperatures should also take into account the date of pollination.

CONCLUSIONS

Results from pollen germination tests at several temperature levels indicate

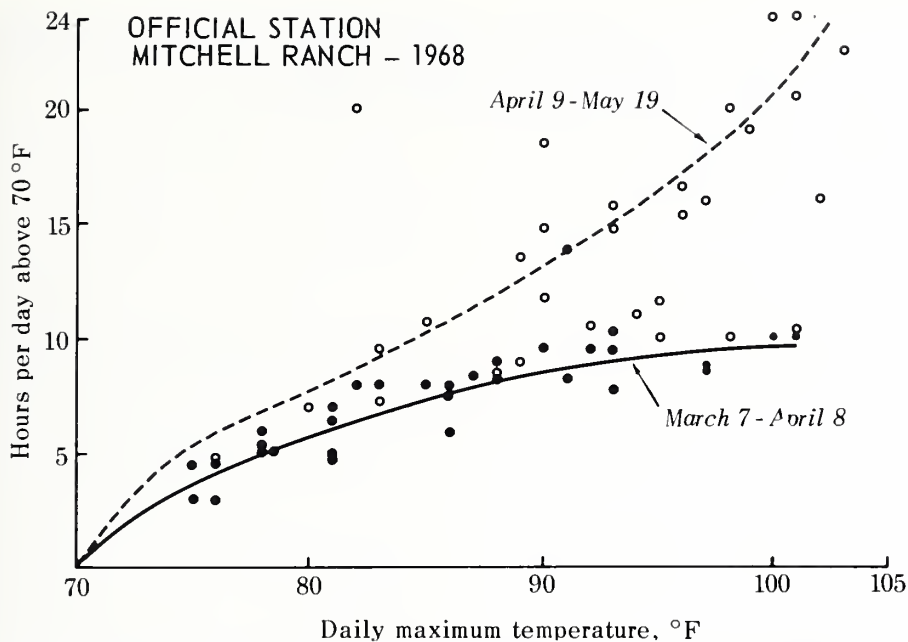


FIG. 5. Hours per day above a base temperature (70°F) as related to various levels of daily maximum temperature for 2 periods during the pollination season at the Mitchell Ranch.

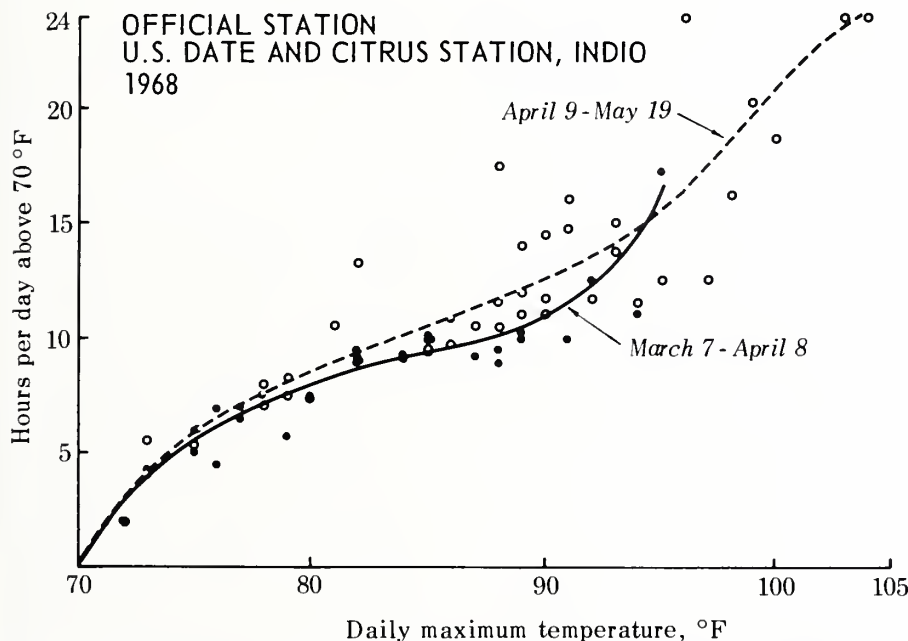


FIG. 6. Hours per day above a base temperature (70°F) as related to various levels of daily maximum temperature for 2 periods during the pollination season at the U. S. Date and Citrus Station, Indio.

clearly that temperature is a factor affecting fruit set (2). However, because ambient conditions fluctuate greatly with time, it is difficult to document the exact effect of temperature on fruit set. The results presented in this report indicate that one should recognize the following facts when conducting field tests to relate daily maximum temperatures to fruit set or when making decisions concerning pollination based on prevailing temperatures.

1. Daily maximum temperatures in the bloom area of tall palms will usually be lower than air temperatures in a U. S. Weather Bureau thermograph shelter at 4½ ft. above ground level. Minimum daily temperatures in the bloom area will usually be higher than in the thermograph shelter. Therefore one should measure temperatures in the bloom area to correlate fruit set accurately with temperature conditions.

2. Daily maximum temperatures by themselves do not indicate the number of hours per day that the temperature is above a given base. The calendar date must be taken into consideration, for later in the pollination season the temperature stays high longer so there will be more hours above a given base.

3. Since wind and garden location also affect the number of hours the temperature is above a base temperature, one must also consider these factors when attempting to correlate fruit set with temperatures which occur at another location. Wind tends to eliminate temperature differences between bloom level and ground level and to decrease the number of hours above a base temperature at either level.

LITERATURE CITED

1. Middleton, Knowles W. E. 1943. Meteorological instruments. 2nd ed. Univ. Toronto Press, Toronto, Canada, 227 p.
2. Furr, J. R., and C. L. Ream. 1968. The influence of temperature on germination of date pollen. Date Growers' Inst. Rep. 45: 7-9.
3. Geiger, Rudolf. 1959. The climate near the ground. Harvard Univ. Press, Cambridge, Mass. 494 p.
4. Brooks, F. A. 1959. An introduction to physical microclimatology. Syllabus No. 397, Univ. Calif., Davis, Calif. 253 p.

THE PERIOD OF RECEPTIVITY OF PISTILLATE FLOWERS AND OTHER FACTORS AFFECTING SET OF DATE FRUIT

C. L. REAM AND J. R. FURR¹

Crops Research Division, Agricultural Research Service,
U. S. Department of Agriculture, U. S. Date and Citrus Station,
Indio, California 92201

INTRODUCTION

The poor sets of fruit obtained in 1967 in some date gardens in which pollen was applied by helicopter aroused the interest of growers in factors that might affect pollination and fertilization of date flowers. Since then we reported that temperatures below about 60°F or somewhat above 100°F were unfavorable for rapid germination and tube growth of pollen (3). Leding (4), working mostly with non-uniform seedlings, pollinated flowers at various intervals after the spathe cracked. He found that receptivity gradually declined after the spathe opened and that low percentages of fruit set if pollination was delayed more than 10 days after the spathe cracked, though some flowers set fruit when pollinated 29 to 33 days after the spathe cracked. Alhert (1) concluded from work done on a seedling of the variety Deglet Noor that the stigma of the date flower is receptive during a period of 15 to 18 days, but for a maximum set of fruit, flowers should be pollinated within 3 or 4 days after the spathe cracks. O. Ruveni², in work recently conducted in Israel on the varieties Khadrawy, Zahidi and Deglet Noor, found that set of fruit declined significantly when pollination was delayed 10 days or more after the spathe cracked.

When fruit set is limited by the amount of available pollen, the viability of the pollen is critical; under such conditions the lower the percentage of germination of the pollen, the lower would be the expected fruit-set.

In tests in artificial media, pollen germination percentages of 45 or more have been considered good. There has been some concern, however, as to the reliability of pollen that shows appreciably less than 45% germination. For example, the question was raised as to whether the application of 2 quarts of pollen with 25% germination would be as effective in inducing set of fruit as one quart of pollen with 50% germination.

Some growers asked whether the time of day when pollen is applied influences the set of fruit. In the Coachella Valley temperatures and winds are commonly higher in the afternoons than in the mornings during the pollinating season and might influence fruit set.

This is a report of the results of work on the following factors that may affect fertilization and fruit set of the date: the period of receptivity of the flower, the viability of pollen used, the time of day when flowers are pollinated, the stage of development at which flowers are recep-

RESULTS AND DISCUSSION

Period of Receptivity of Pistillate Flowers. To study the course of decline in receptivity of date flowers in 1968, we selected 24 similar 10-year-old Deglet Noor palms that were isolated from male palms. As the spathe cracked they were removed and a tag bearing the date of opening was attached to each inflorescence. On 12 trees the inflorescences were covered with bags for exclusion of air-borne pollen; those on the other 12 trees were not covered. On each group of 12 trees 114 inflorescences were tagged. After 20 days the bags were removed and all inflorescences that had emerged were pollinated. Another lot of inflorescences was tagged during the next 20 days and pollinated at the end of the period, the entire operation covering a period of 40 days. Thus, flowers of some bunches were pollinated on the day the spathe opened and others after various periods up to 20 days after the spathe opened. After pollination, all bunches were left uncovered. On September 1, in the late khalal stage of the fertilized fruit, random samples of 5 strands were taken from each bunch and counts made of fruit and flower scars. The normal khalal fruit were assumed to have fertilized seed; the green fruit were assumed to be unpollinated and seedless. The samples of fruit cut substantiated these assumptions. The total number of flowers produced on a strand was determined from the total count of fruit and flower scars.

The percentage of flowers on each bunch that set fruit with seed was calculated, and since the difference in mean percentage set of fruit on the bagged and unbagged bunches was not significant, the data from the two groups were combined. The percentage of fruit set on each bunch was plotted on a scatter diagram and a freehand curve drawn to represent the trend in percentage set in relation to lapsed time from opening of the spathe to pollination (Fig. 1). Fruit set dropped sharply on bunches pollinated more than 13 days after the spathe cracked. The percentage of fruit set on bunches pollinated within a week after the spathe cracked was higher than that on bunches pollinated after a longer interval. The set on 43 bunches out of 138 pollinated within a week after the spathe cracked was 60% or above, while on those pollinated after a longer interval only 8 out of 90 bunches had a set of 60% or above. The percentage set of the average bunch was satisfactory to about day 13, when an average of 50% set was obtained. The bunches used in this test had been cut back at the tips and thinned to 40 strands of about 48 flowers per strand. A 50% set produced bunches of about 950 to 1,000 fruits, weighing about 22 or 23 lb. each.

In other years the period of receptivity may differ from that in 1968. Our results

and those of other workers suggest that delaying pollination for 7 days after the spathe cracks is usually safe, and that probably satisfactory sets may be obtained for 10 days after the spathe cracks. A delay in pollination of more than 10 days, however, may result in a greatly reduced fruit set.

Influence of Pollen Viability on Fruit Set. We conducted pollination tests with 5 different lots of pollen that had been tested for germination in a modified Brewbaker and Kwack medium (2). Some lots of pollen were fresh; others had been stored for a year or more. The germination percentages of the different lots were 78%, 45%, 40%, 36% and 9%.

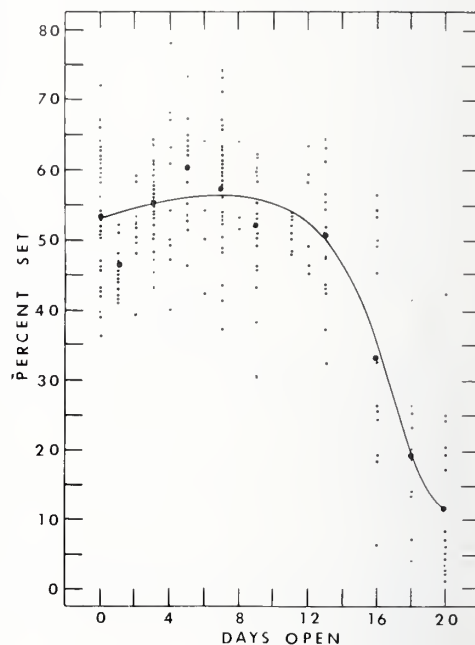


FIG. 1. The effect of delay after the spathe cracked in pollinating Deglet Noor flowers on fertilization of the ovules and set of fruit. Small dots, percentage set of individual bunches; large dots, mean percentage set on days when 12 or more bunches were pollinated.

One inflorescence on each of 9 Deglet Noor palms was pollinated with each of these 5 lots of pollen. On each tree spathe were removed from 5 inflorescences when the spathe were judged to be nearly ready to open. The inflorescences were immediately covered with bags to prevent contamination by air-borne pollen. With precautions to prevent contamination by unwanted pollen, we loaded the 5 lots of different pollen

¹Agricultural Research Technician and Research Horticulturist, respectively.

²Personal communication.

into separate small dusters. The different pollens were applied to the inflorescences to which they had been assigned by inserting the duster spouts through small holes in the paper bags and thoroughly dusting the flowers inside the bags. After 2 weeks the bags were removed from the inflorescences. In September the percentage of fertilized fruit was determined from counts of fruit and flower scars on samples of 5 strands per bunch. From these data (Table 1) it is clear that the small differences in set of fruit induced by the different lots of pollen are not significant. In this test, in which an excess of pollen was applied, there was little apparent relation between pollen viability and set of fruit. In pollen lots with low percentages of germination there were same pollen grains capable of effecting fertilization. The effectiveness of pollen in inducing fruit set may not, however, be proportional to its percentage of germination in an artificial medium.

TABLE 1. The relation of pollen germination to set of Deglet Noor fruit

Tree No.	Pollen germination — per cent ^a				
	78	40	36	9	45
Fruit set — per cent					
4—6	70	38	—	49	54
4—7	58	46	46	54	65
4—8	53	37	30	50	52
5—6	46	45	39	32	43
5—7	34	48	34	30	48
5—8	52	42	49	38	58
6—6	55	39	40	43	55
6—7	48	33	28	27	40
6—8	38	38	38	43	38
Average	50	41	38	41	50

^a Germination tests of pollen conducted in artificial medium (2).

Time of Day When Flowers are Pollinated. We pollinated approximately equal numbers of inflorescences between 7 and 10 AM and 1 and 3 PM on the same day on 10 Medjool trees. The 26 bunches pollinated in the morning had an average set of 36% and the 24 pollinated in the afternoon had an average set of 35%. This result suggests that time of day when pollination occurs was of little importance in this trial, but extensive tests involving many days during a number of seasons would be required to fully answer the question.

Stage of Development at Which Flowers Become Receptive. We attempted to determine the approximate stage of development at which date flowers become receptive by pollinating inflorescences at several stages of development, and then applying a fungicide (sulfum-ferbam) at intervals after pollination to inhibit germination or tube growth of pollen on the stigmatic surfaces after the flowers were dusted with the fungicide (5). The effect of the fungicide, which was composed of 19 parts dusting sulfur and 1 part ferbam, on germination and tube growth of date pollen was tested in modified Brewbaker and Kwack medium (2). At concentrations of 50 and 100 mg of the fungicide in 100 ml of the culture medium germination was virtually inhibited, though 0.4% of the pollen grains showed slight tube growth before they were killed. It seems unlikely that pollen germinated and effected fertilization of many flowers on an

inflorescence after it was dusted with the fungicide.

On each of 15 Deglet Noor trees 5 bunches were pollinated. When the first spathe on each tree cracked, it and the next 4 younger ones were removed and the flowers pollinated. At intervals of 1, 2, 4, 6 and 8 days after pollination, 3 inflorescences representing each combination of development stage and time after pollination were dusted with fungicide; thus there were 3 replications of each treatment and a total of 75 treated bunches.

The bunches were thinned in the usual manner to 40 strands. In September, flower scars and fruit were counted on samples of strands from each bunch to determine the percentage of fertilized fruit that set. The results show that set was relatively high on the older bunches and on those on which dusting with fungicide was delayed for 6 or 8 days after pollination (Table 2). The application of fungicide up to 4 to 6 days after the inflorescences were pollinated seems to have reduced set of fruit, even on the oldest bunches. The cause of the reduction in set, however, was not clear. It may have been entirely due to prevention of germination or tube growth of the pollen; there may have been considerable variation in the time at which flowers became receptive; or some flowers may have been injured by the fungicide. Judging from the rate of pollen germination and tube growth in an artificial medium, one would suppose that on receptive flowers the pollen tube would have grown in 1 or 2 days beyond the stage at which it would be injured by the fungicide. If it is assumed that the flowers were not injured, these results suggest that relatively few flowers are receptive when the spathe cracks and that they do not all become receptive for possibly 6 days of more after the spathe cracks. The results obtained in this test were, however, inconclusive because of the possibility that some of the flowers were injured by the fungicide.

TABLE 2. The stage of development (age) of flowers in relation to receptivity and percentage of fruit set. Fungicide^a dust used to stop pollen germination and tube growth

Relative age of bunch	Time from pollination to dusting with fungicide Days:				
	1	2	4	6	8
	%	%	%	%	%
1 (oldest)	31.7	33.0	33.7	44.3	59.0
2	13.7	42.3	28.7	44.7	55.7
3	17.5	31.3	31.0	42.0	39.0
4	10.3	28.0	7.0	35.3	43.3
5 (youngest)	19.5	12.0	9.7	24.7	38.0

^a A mixture of dusting sulfur and ferbam.

SUMMARY

Inflorescences on 24 Deglet Noor palms were pollinated at various intervals up to 20 days after the spathes cracked open. After the spathe cracked, delay in pollinating up to 7 days did not cause a decrease in fruit-set; further delay to 13 days caused moderate reductions; and delays exceeding 13 days greatly reduced fruit-set. These results are in general agreement with those of other workers and indicate that delays of more than 10 days may greatly reduce fruit-set. When an excess of pollen was applied, fruit-set on bunches pollinated

with pollen of low viability (germination in artificial medium 9%—45%) was about as great as that on bunches pollinated with pollen of 78% germination. Fruit-set on bunches pollinated between 7 and 10 AM was about the same as on those pollinated from 1 to 3 PM. Results of a test to determine the stage of development at which flowers become receptive to pollen were inconclusive, but indicated that few flowers were receptive before the spathe cracked and that not all had become receptive several days after the spathe cracked.

LITERATURE CITED

1. Albert, D. W. 1930. Viability of pollen and receptivity of pistillate flowers. *Date Growers' Inst. Rep.* 7: 5-7.
2. Furr, J. R., and V. M. Enriquez. 1966. Germination of date pollen in culture media. *Date Growers' Inst. Rep.* 43: 24-27.
3. Furr, J. R., and C. L. Ream. 1968. The influence of temperature on germination of date pollen. *Date Growers' Inst. Rep.* 45: 7-9.
4. Leding, A. R. 1928. Determination of length of time during which flowers of the date palm remain receptive to fertilization. *J. Agr. Res.* 36: 129-134.
5. McDaniels, L. H., and J. R. Furr. 1930. The effect of dusting sulfur upon the germination of the pollen and the set of fruit of the apple. *N. Y. (Cornell) Agr. Exp. Sta. Bull.* 499: 1-13.

DEVELOPING GROUND LEVEL EQUIPMENT FOR POLLINATING DATES

G. K. BROWN, R. M. PERKINS AND E. G. VIS¹

The research discussed in this report was conducted during 1968 and is a continuation of the pollination research project initiated in the spring of 1966 by the U. S. Department of Agriculture with the cooperation of the California Agricultural Experiment Station.

The conventional methods of pollinating dates are described in another report covering the evaluation of aircraft methods of pollination (2). A review of other pollination methods for both date and oil palm is also included.

Helicopter and fixed-wing aircraft pollination experiments were very encouraging in 1966, but development and evaluation of methods using ground based equipment were initiated because of the poor results obtained in gardens where pollen was applied by helicopter during the spring of 1967.

EXPERIMENTAL APPROACH

Mechanized methods of pollinating are needed to balance labor requirement with labor supply. Fig. 1 shows the estimated total number of workers employed each week in various date field operations. In 1961, a peak of about 750 workers were used in pollinating compared to a peak of about 250 workers in 1967. Because the helicopter method was used on about 500 acres in 1967 the number of workers used was about 50 less than would have been required had this acreage been hand pollinated. This means that a peak of about 300 workers would have been used for pollination in 1967. Part of the remaining difference between 1961 and 1967 is the result of a reduction in the number of times each palm was pollinated and part is due to a shortage of workers available for pollination. As a result, date bunches having poor fruit set and unpollinated fruit are appearing more often than in 1961. To increase the number of days before the palm must again be pollinated, the worker now opens more of the large unopened spathes than formerly.

For mechanized pollination methods to accomplish the task with a labor supply of about 200 workers, it appears that labor requirements must be reduced by about 50%. In addition to reducing labor requirements, a successful method must also result in yield and fruit quality which will not reduce grower returns. Several methods of pollinating from ground level were analyzed from the standpoint of potential reduction in labor requirements as well as potential for maintaining grower returns. Two methods were selected for field evaluation.

One method, conceived and developed by employees of the field department of California Date Growers' Association, is shown in Fig. 2. A date harvesting tower was used to move a worker around the bloom area as he applied dry pollen to the emerging bloom with a compressed-air bloom duster based on the principle described by Alexander (1). The bloom duster operated at a static pressure of 30-40 psi and used a tube of 1/8-inch inside diameter and about 2 ft long to direct the pollen at the bloom. This method required 2 workers per tower (one operator and one pollinator) and had an expected work rate of about 50 palms, or one acre, per hr.

The second method, using a trailer-mounted palm duster, was conceived and developed by the authors and is shown in Fig. 3. The duster operator stood on a fixed height platform 12 ft above ground level and directed a delivery pipe at the bloom area of the palm. The delivery pipe was counterbalanced and gimbal-mounted in the floor of the platform. The pipe within the operator's reach was 3-inch PVC plastic, for electrical safety, and the upper portion beyond the reach of the operator was 2-inch aluminum irrigation pipe topped by a 3/4-inch nozzle, for light weight and rigidity. The dusting nozzle was about 30 ft above ground level. A "Roots" type blower provided about 125 cfm of air to convey a pollen-flour mixture (1 part

pollen + 6 parts 'Wondra'² flour) at about 450 mph as it left the nozzle.

Since dusting materials cannot be conveyed through this type of blower, it was necessary to meter the pollen mixture into the pressurized air stream from an airtight hopper. This was accomplished by using two 1/2-inch diameter car bits, turning at about 150 rpm, located in horizontal pipes at the bottom of the hopper. This hopper was similar in design to those used for helicopter application of pollen in 1966 (2).

This method of pollination also required 2 workers per duster (one tractor driver and one pollinator) and had an expected work rate (at 1 1/2 mph) of about 5 acres per hr if only one pass was required to dust the entire palm, or 2 1/2 acres per hr if one pass on each row side was required to dust the entire palm.

Each experimental method was used to pollinate about 2 acres of palms at the Valley Center Ranch. Palm heights at this ranch varied considerably and the distance from ground level to the bloom

² Gold Medal Wondra instantized flour was used. This type of flour did not bridge in the hopper, whereas regular bleached flour did bridge. Wondra is a trade name and is used for clarity only and does not imply endorsement by the USDA.

TABLE 1. Schedule of pollen applications

Pollination method	Application dates ^a			
	March	April	May	Total
Palm duster	26, 29	05, 09, 12, 16, 19, 23, 26	03	no. 10
Bloom duster	27, 30	05, 09, 12, 16, 19, 23, 26	finished	9
Hand control	23	12, 26	finished	3

^a Irrigations on March 30 and April 26 delayed pollination about a week.

TABLE 2. Fruit yield and quality summary for 1968 pollination experiments at Valley Center Ranch on the variety Deglet Noor

Pollination method	Pollinated ^a fruit in lot	Pollinated fruit yield/palm ^b	Fruit/lb.	Pollinated fruit production			Small fruit in culls
	%	lb.		Marketable	Products	Culls	
Palm duster				%	%	%	%
1 Side	98	350	54	72	14	14	2
Palm duster							
2 Sides	98	342	58	69	17	14	8
Bloom duster	100	372	68	41	23	36	26
Hand-pollinated control	99	357	57	71	20	9	9

^a Percentage of pollinated fruit in lots received at packinghouse.

^b To simplify yield comparison, this yield is adjusted so that all methods have 16 bunches per palm. Yield was averaged over all palms in each respective plot without regard to the differences in fruit set and palm height (distance from ground level to the bloom area) shown in Figures 5-12.

¹ G. K. Brown and E. G. Vis are Agricultural Engineers, Harvesting and Farm Processing Research Branch, Agricultural Engineering Research Division, ARS, USDA, Riverside, California. R. M. Perkins is Associate Specialist, Agricultural Engineering Department, University of California, Riverside, California.

area varied from a low of 32 ft to a high of 48 ft. The palm duster was used to apply pollen from one side of the palm in one plot and from 2 sides of the palm in another plot.

During the pollination period, we applied by each method a total of about 3 quarts of pollen per acre. Applications were repeated every 3-4 days between March 26 and May 3. Records were kept of the date of application and daily air temperatures. Pollen viability was between 50 and 60%. Blooms were numbered in selected palms in each plot and their stage of development noted at weekly intervals. Fig. 4 shows the appearance of blooms at what was termed 'cracked', 'partial', and 'open' stages.

The plots were harvested between November 25 and December 4, 1968. The numbered bunches in selected palms were harvested individually to obtain fruit set information. Fruit set was estimated for each numbered bunch on the selected palms by counting the number of fruit strands on each bunch, measuring the fruiting length of the strands (to the nearest inch) and dividing the total fruiting length of the bunch by the total number of fruit on the bunch. This method is subject to some error and variation because of differences in bunch shape and judgment as to fruiting length, but it should be correct to within $\pm 10\%$ and is a fairly rapid method of evaluating bunches.

The remaining palms in each plot were mechanically harvested by commercial methods. Records of yield, per cent unpollinated fruit present, fruit size and quality were obtained from receiving records provided by California Date Growers' Association.

RESULTS

Schedules of pollen applications are shown in Table 1. Irrigation interfered with equipment operation in the garden for 2 periods of about 7 days, starting March 30 and April 26. The work rates, acres or palms per hr, were about as expected.

Yields and fruit-quality data for all plots are shown in Table 2. The yield for all plots has been standardized at 16 bunches per palm to simplify the comparisons. The average number of bunches

per palm for each plot varied from 15.3 to 17.7. Both plots pollinated with the palm duster were slightly low in yield, while fruit size was similar to or slightly larger than the hand-pollinated control.

Using packing house receiving grades and fruit values of 10.5 c/lb. for marketable, 5 c/lb. for products and nothing for culls, we calculated gross returns per palm to be \$28.89, \$27.69, \$20.30, and \$30.20 for the palm duster (1 side), palm duster (2 sides), bloom duster, and hand pollination respectively. The estimated savings in pollination cost when using the palm duster (including the purchase and operation of equipment) would have given a net return equal to that of hand pollination. Estimated savings in pollination cost using the bloom duster would not have offset the lower grower returns, however, the low gross return per palm of \$20.30 was due to poor fruit size which could have been corrected by proper thinning.

Because light fruit set was anticipated, the bunches pollinated with these experimental methods were thinned only 5 to 10% by making one center cut on the larger bunches, compared to at least 15% thinning on all hand-pollinated bunches.

An attempt was made to correlate temperature during pollination with fruit set for each bunch, but the only conclusion reached was that the temperatures experienced during this experiment did not adversely affect fruit set. Figs. 5 through 12 show the relation of fruit set, on blooms which were "partial" 3 days before pollen application, to heat units accumulated for 3 days following pollen application. These heat units were obtained by summing the daily difference between the maximum temperature and 65°F. All pollen applications were made in the late morning, so the day of pollination and the 2 following days were included in calculating heat units for each bunch. The palm average data are shown without regard to accumulated heat units.

Results of pollination with the palm duster show that fruit set of the tallest palms was poorer than that of the medium or short palms and that the variation in results was decreased by applying pollen from 2 sides of the palm. These results indicate that the palm duster should adjust to the height of each palm

rather than operate from a fixed elevation. Pollination with the bloom duster resulted in better fruit set than with the palm duster, better, in fact, than hand pollination, which averaged 0.62 inches of strand per pollinated fruit. Variation in fruit set was less with the bloom duster than with the palm duster. Possible reasons for these results may be that pollen was applied directly to each bloom, regardless of bloom height; more applications were made with the bloom duster than with hand pollination; and bunches pollinated with the bloom duster were thinned less, which may have reduced the tendency to shed fruit during June drop. Time available during the pollina-



FIG. 2. Bloom duster method of pollination.



FIG. 3. Palm duster method of pollination.

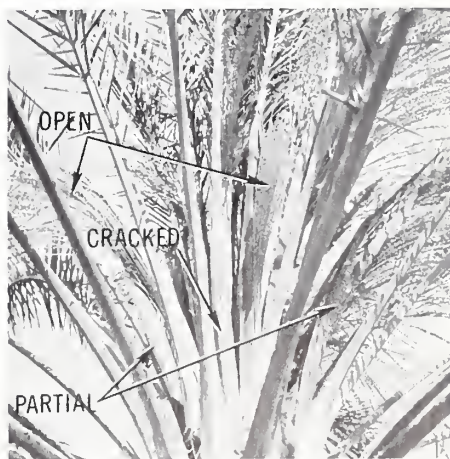


FIG. 4. Deglet Noor date blooms at various stages of opening.

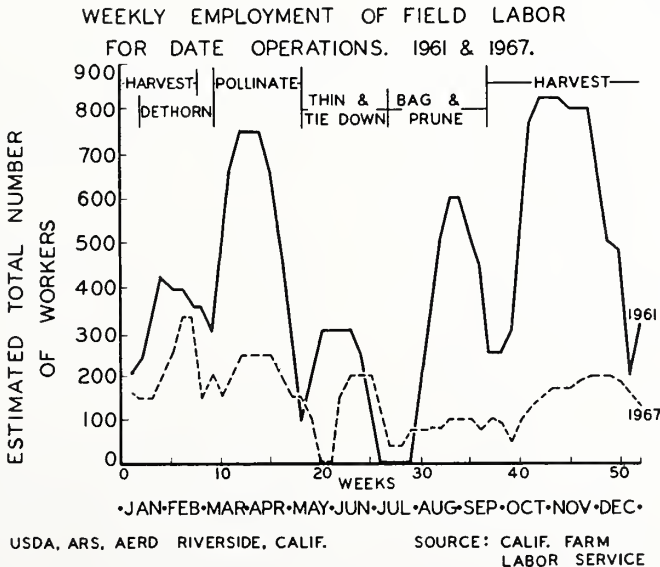


FIG. 1. Weekly employment of field labor for date operations.

tion period did not allow a detailed study of hand-pollinated bunches.

The Valley Center Ranch was one of those pollinated by the helicopter method in 1967. The resulting yield of pollinated fruit with the helicopter method was 5,480 lb. per acre with an average fruit set of 3.2 inches per fruit. The difference between temperature patterns for 1967 and 1968 can be seen in Fig. 13 where the maximum temperature occurring the day of pollination has been plotted against the accumulated per cent of total applications for the season. These data show that about 78% of the applications in 1967 were made on days which reached a maximum temperature of 85° or less, whereas about 75% of the applications in 1968 were made on days which reached a maximum of 85° or more.

The temperature pattern in 1966, when results from aircraft pollination were encouraging, was warmer than in 1968 (3). In spite of this the fruit set obtained in 1968 was better than the best results obtained with aircraft in 1966. This is probably the result of concentrating pollen in the bloom area of the palm with these duster methods.

DISCUSSION

The palm duster method resulted in less fruit set than hand pollination. Yield and grower return for the two methods

were about equal because each bunch was thinned according to its fruit set. Results for the short palms suggest that average fruit set can be improved if the duster elevation can be adjusted for each palm.

Fruit set resulting from use of the bloom duster was equal to or better than that resulting from hand pollination, but because bunches pollinated with the bloom duster were not thinned enough, the fruit size was poor, fruit shrivel occurred frequently, and grower return was reduced by about one-third. If these bunches had been more heavily thinned, the fruit size and quality should have been similar to that for hand pollination and thus grower return should have been similar.

The results presented here are considered exploratory and might not be the same if the test had been conducted at other ranches in the valley or if repeated at the same ranch in succeeding years. Temperature trends for the date-producing areas of the Coachella Valley have been studied (3) as a part of the fruit set - temperature correlation work of this project. Differences between the temperature at Indio Weather Station and at weather stations in date gardens and in the bloom area of the palm have also been studied (7). Furr and Ream (5)

determined the effect of various levels of constant temperature on the germination of date pollen. Additional field information on the correlation between temperature and fruit set is still needed to define the risk involved in using these pollination methods. Reuther (6) reported that hand pollination resulted in poor fruit set in some years, and that placing a brown paper bag over the bloom following pollination raised the bloom temperature and improved results. None of the experimental methods evaluated so far would allow for such haggling.

If these pollination methods are to be used by the industry, it appears that some additional points should be kept in mind. The quantity of pollen required per acre with the palm duster method will probably be 3 quarts or more, so growers should plan to increase the number of male palms and improve the pollen collection procedure. Pollen with a high and dependable viability is essential if these methods are to be used with confidence. Observations of results obtained with the helicopter method in 1967 suggest that nutritional levels may have a considerable effect on fruit set also. It may be desirable to change irrigation practices somewhat during pollination. The one-week delay in pollination early in the season reduced average fruit set 5-8% on bunches which opened dur-

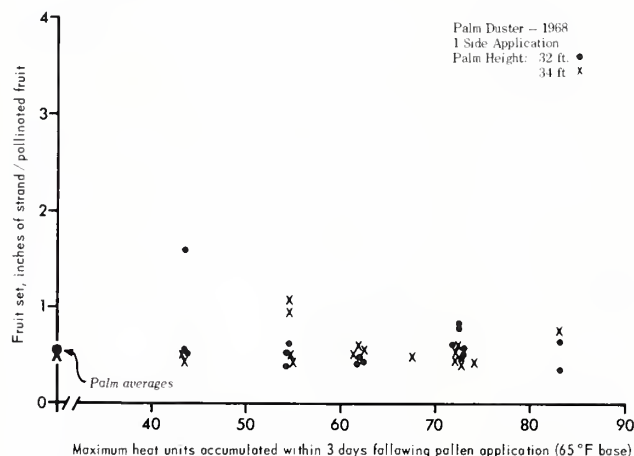


FIG. 5. Correlation of fruit set with heat units, one side application with palm duster on short palms.

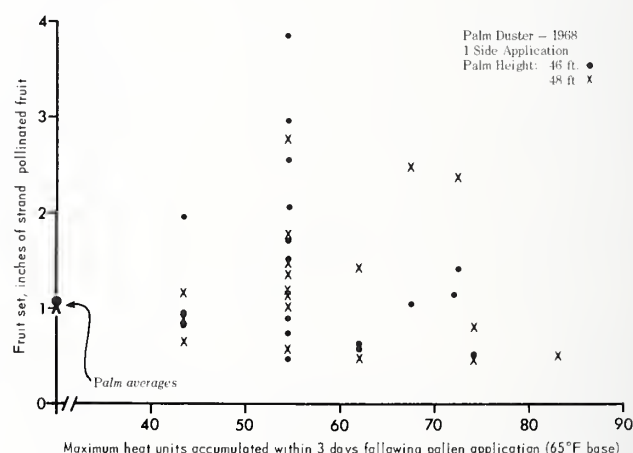


FIG. 7. Correlation of fruit set with heat units, one side application with palm duster on tall palms.

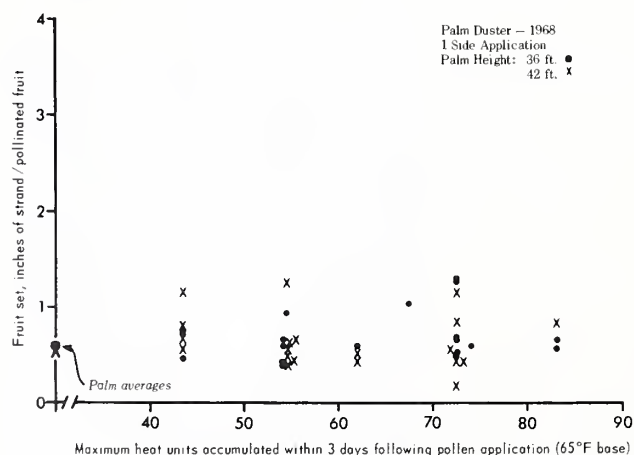


FIG. 6. Correlation of fruit set with heat units, one side application with palm duster on medium height palms.

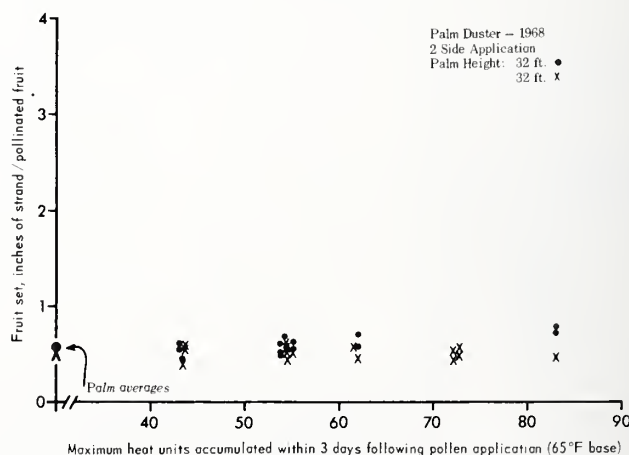


FIG. 8. Correlation of fruit set with heat units, two side application with palm duster on short palms.

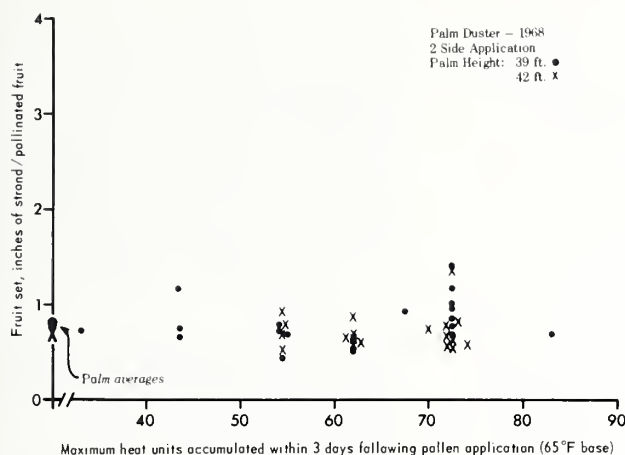


FIG. 9. Correlation of fruit set with heat units, two side application with palm duster on medium height palms.

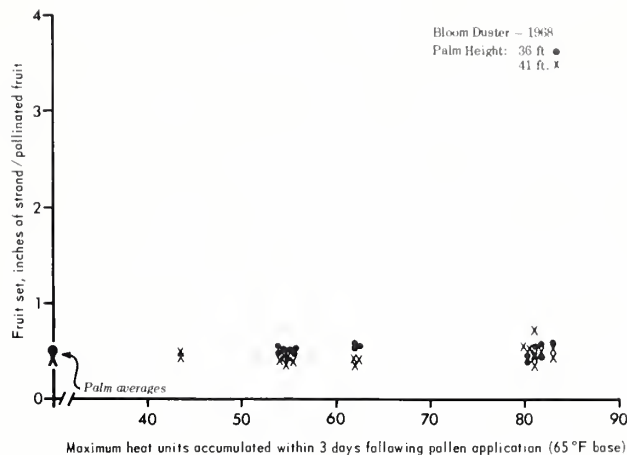


FIG. 11. Correlation of fruit set with heat units, bloom duster on short palms.

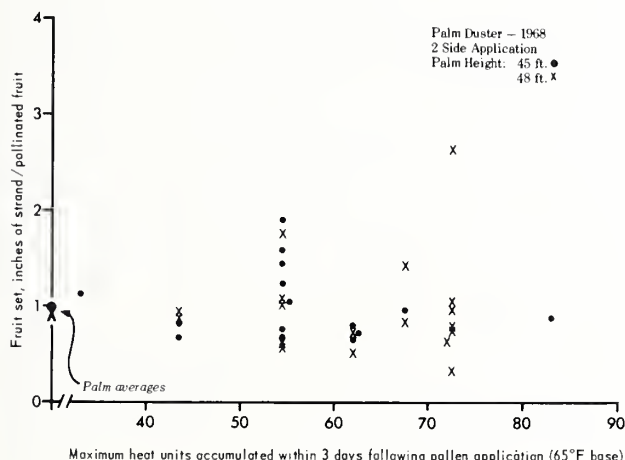


FIG. 10. Correlation of fruit set with heat units, two side application with palm duster on tall palms.

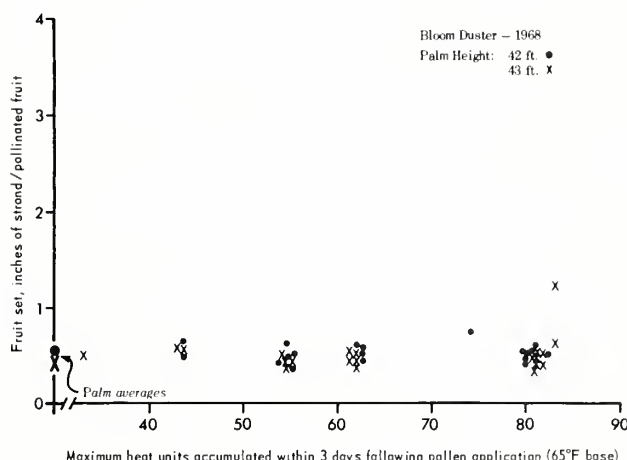


FIG. 12. Correlation of fruit set with heat units, bloom duster on medium height palms.

ing that period in the palm duster plots. Fruit set on similar bunches in the bloom duster plot was reduced an average of 1%. Irrigating in furrows, near the palm trunks, rather than flooding the entire row would allow equipment operation at any time and in addition may increase the temperature of the garden by 1 or 2 degrees.

For either of the pollination methods to be practical from the standpoint of labor requirements and machine investment, the interval between applications will need to be increased to about 7 days. At that point the bloom duster would be a practical method of using existing harvesting towers, but the purchase of enough additional towers to cover the total date acreage would be prohibitive because of the low work rate of one acre per hr. The palm-duster method would require less than half the number of machines required with the bloom duster method and the cost of each palm duster would be about $\frac{1}{3}$ of that of a harvesting tower. The palm duster can also be used to improve the application of pesticides (4), especially to tall palms. While more palm

dusters would be required for pollination than for pesticide application, such multiple use would reduce the cost for each operation so that the equipment investment could be offset by savings in pollination and dusting costs.

Experiments using an elevating palm duster, applying pollen to 2 sides of the palm at 4 and 7 day intervals, and the bloom duster operated at 4 and 7 day intervals will be conducted in 1969. Each treatment will be replicated in an attempt to improve the reliability of the results. Records of bloom development, pollen viability, temperature and bloom nutritional levels will be obtained.

SUMMARY AND CONCLUSIONS

Two methods of pollinating date blooms using ground-level equipment were evaluated during the spring of 1968. Fruit set following use of the palm duster method was poorer than that following hand pollination, but yields and fruit quality were about equal as a result of decreased thinning of the duster-pollinated bunches. Fruit set resulting from use of the bloom duster method was

equal to or better than that resulting from hand pollination, but, because the bunches pollinated with the bloom duster were not thinned enough, the fruit size and quality were poor; proper thinning would have resulted in yields and grades similar to those obtained with hand pollination.

Both experimental methods require a greater quantity of pollen per acre and pollen of more dependable quality than is required by hand pollination. While temperature has been shown to affect fruit set, as well as the rate and level of pollen germination, the temperatures experienced during these tests did not appear to have an adverse effect. Nutritional differences as well as temperature differences between gardens may affect the results obtained with these pollination methods.

For either of these experimental methods to be practical from the standpoints of labor requirement and machine investment, the interval between pollen applications must be increased to about 7 days.

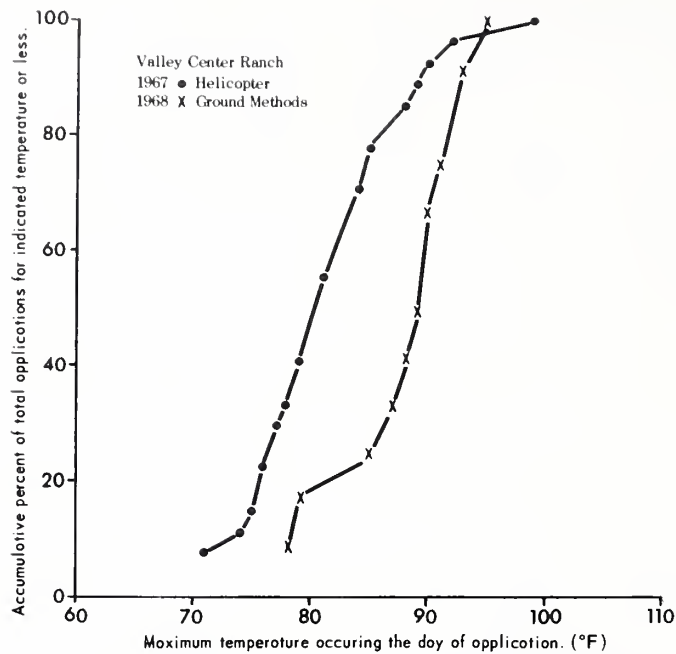


FIG. 13. Comparison of accumulative per cent of total applications of pollen with the maximum temperature on the day of application for 1967 and 1968.

LITERATURE CITED

1. Alexander, D. B. W. 1952. A method of pollinating dates. Date Growers' Inst. Rep. 29:20.
2. Brown, G. K. and R. M. Perkins, 1969. Experiments with aircraft methods for pollinating dates. Date Growers' Inst. Rep. 46:_____.
3. _____, _____, and E. G. Vis. 1969. Temperature and heat unit occurrences during date pollination in the Coachella Valley of California. Date Growers' Inst. Rep. 46:_____.
4. _____, _____, and _____. 1969. An improved pesticide duster for date palms. Date Growers' Inst. Rep. 46:_____.
5. Furr, J. R. and C. L. Ream. 1968. The influence of temperature on germination of date pollen. Date Growers' Inst. Rep. 45: 7-9.
6. Reuther, W. and C. L. Crawford. 1946. The effect of temperature and bagging on fruit set of dates. Date Growers' Inst. Rep. 23:3-7.
7. Vis, E. G., G. K. Brown, and R. M. Perkins. 1969. The effect of elevation and time on air temperature during date pollination. Date Growers' Inst. Rep. 46:_____.

EXPERIMENTS WITH AIRCRAFT METHODS FOR POLLINATING DATES

G. K. BROWN AND R. M. PERKINS¹

The research discussed in this report was conducted during the pollination seasons of 1966 and 1967 by the U.S. Department of Agriculture with the co-operation of the California Agricultural Experiment Station. All pollination tests were made in the Coachella Valley of California on Deglet Noor palms. This valley produces more than 98% of the United States date production and the Deglet Noor accounts for 92% of the valley production.

Hand pollination (8), an ancient practice in date palm culture, has been used in California since commercial date production began about 1920. Methods of simplifying this task have been considered by various individuals. Some growers have placed whole, or parts of, male blooms in several female palms in a garden hoping to provide enough wind-borne pollen to achieve satisfactory fruit set. Alexander (1) developed a pollinating tool which could be used to blow dry pollen into newly opened blooms from the ground. This method has been used successfully by at least one grower in the Coachella Valley (11) and by growers in Israel. Pollen applications were made frequently when this method was

used because the blooms were allowed to open naturally and therefore did not become fully exposed until one to two weeks after cracking of the spathe. A few growers have applied pollen with pesticide dusters when bloom occurred quickly and workers were unable to pollinate fast enough by normal hand pollination methods. Although careful application and favorable weather conditions sometimes resulted in good yields, results with each of these alternate methods apparently were not consistent enough for them to be considered satisfactory by most growers.

Similar pollination problems face the oil palm industry in Malaysia and have been studied in our attempts to evolve mechanical pollination methods for date palms. The oil palm is monoecious. Separate male and female blooms are produced by the same palm in cycles, resulting in variations of the ratio of female to male bloom on a palm during the year. Studies of natural pollen dispersal have shown that most of the pollen remains below the palm canopy, especially at bunch level, and that the incidence of air-borne pollen is quite variable (7). Oil palm growers in some plantations in Malaysia have a standard practice of collecting male blooms, drying the pollen and applying it by hand to female blooms on young trees in order to obtain normal crops (6). Hand pollination results in more uniform production throughout the year and induces a more evenly balanced production of male and female blooms than does natural pollination (6). Pollinating poles, rotary hand dusters and motorized back-pack dusters have been used to increase the number of palms a worker can pollinate (12).

The date industry has had difficulty in recruiting workers for hand pollination. From 1961 to 1967 the total number of workers employed in pollination decreased by 60% while the acreage remained fairly constant (3).

Discussions with the date industry in 1965 indicated that a mechanized pollination method was needed which would substantially reduce the labor requirements for pollination. Aircraft pollination experiments had been conducted by Preston (9, 10) using a fixed-wing crop duster. A pollen-application project involving both helicopter and fixed-wing aircraft was initiated after reviewing Preston's results, the information on the alternate pollination methods previously discussed and the suggestions of various industry and research groups.

OBJECTIVES

For a mechanized pollination method to be successful it must: 1) result in enough fruit set so that yields and grower returns at least equal those of hand pollination; 2) be dependable throughout the pollinating season and from year to year; 3) attain 1 and 2 without exceeding the quantity of pollen which can be economically obtained (hand pollination requires about 1 quart or 58 in³/acre/season); 4) require no more labor than the labor supply considering the fact that the blooms will still have to be thinned and tied down by hand (normally during hand pollination bunches are thinned and a string tied around the strands to prevent them from becoming entangled with fronds, thus facilitating the tie-down operation).

Agricultural Engineer, Harvesting and Farm Processing Research Branch, Agricultural Engineering Research Division, ARS, USDA, Riverside, California and Associate Specialist, Agricultural Engineering Department, University of California, Riverside, California, respectively.

¹Reuveni, O. 1968. (Private Communication). The Volcani Institute of Agricultural Research, Israel.

TABLE 1. Summary of 1966 pollen application data

Plot code ¹	Aircraft application							Hand application				Remarks
	Pollen ²	Rate ³	Frequency ⁴	Deposit ⁵	Number ⁶	Start ⁷	Finish ⁷	Type ⁸	Number ⁶	Start ⁷	Finish ⁷	
H - 1	3	14.4	4		15	03/17	05/17	PP & CB	3	04/09	05/13	Frequent wind. Wrong thinning, unreliable data.
H - 2	3	14.4	4	10.6	13	03/27	05/17	PP & CB	3			Same as above.
H - 3	1	4.8	4		15	03/17	05/17	PP & FB	4	03/22	05/22	Usually calm.
H - 4	1	4.8	4	3.3	15	03/17	05/17	PP & CB	3	03/20	04/28	Frequent wind.
H - 5	3	7.2	2	6.2	24	03/27	05/19	PP & CB	3			Occasional wind.
H - 6	3	7.2	2		28	03/17	05/19	PP & CB	3			Frequent wind.
H - 7	1	2.4	2	5.5	26	03/23	05/19	FB & CB	3			Usually calm.
H - 8	1	2.4	2		26	03/23	05/19	FB	3			Usually calm.
F - 9	1½	7.2	4	4.9	13	03/31	05/19	PP & CB	4	03/19	04/29	Occasional wind.
F - 10	1½	7.2	4		11	04/04	04/19	FB	3			Unusually poor set in all plots.
F - 11	3	7.2	2		22	03/31	05/19	PP & CB	3	03/29	05/06	Usually calm.
F - 12	3	7.2	2	5.0	22	03/31	05/19	FB	3	04/06	05/19	Occasional wind.

¹H = Helicopter; F = Fixed-wing; numbers designate individual plot.

²Nominal amount of pollen (quarts, liquid measure) required per season to pollinate 1 acre of palms.

³Cubic inches of dry pollen applied per acre on each application.

⁴Scheduled number of days between pollen applications.

⁵Average number of pollen grains per cm² deposited on glass slides by each application, determined by counting the number of grains observed in three passes across a 75 mm glass slide at a 100x magnification.

⁶Total number of applications at each plot.

⁷Month and day of first or last application.

⁸PP = Pollen puffer; CB = Cotton ball; FB = Fresh bloom.

DATE POLLEN CHARACTERISTICS

Dry date pollen is ellipsoidal and about 12 microns wide by 24 microns long. A container of pollen appears as smooth, free-flowing powder and has a bulk density of about 0.41 oz/in³. It is also: susceptible to damage by moisture, quickly damaged by temperatures of 140°F or above, damaged by mechanical abrasion, keeps at least one year at temperatures of 0-40°F without a significant decrease in viability if kept dry, and can be mixed, stored, and applied with certain diluents.

PRELIMINARY TESTS

Pollen Distribution from Helicopter.

Technical information available from the Bell Helicopter Company (2) suggested the possibility of releasing pollen at the proper location in the rotor wake so that a band of pollen would be moved through the bloom area of the palms, then would disperse and continue to swirl in the tops of the palms due to the action of the vortices existing on both sides of the wake.

Evaluations of this technique were conducted in the first 3 months of 1966 in co-operation with Western Helicopters, Inc. of Rialto, California. Initial tests consisted of observing the direction in which red-colored flour moved when discharged from single pipes located on each side of a series 47G-3 Bell Helicopter.

Pollen placement tests were then conducted over date palms at Indio, California, for various flight speeds and locations of the dust outlets using: 1) visual observations; 2) 16mm cameras operating at 64 frames per second, focused on a grid mounted in the bloom area of a palm; and 3) a count of the pollen grains deposited on various arrangements of glass slides which were coated with a mixture of Vaseline and detergent and mounted in the bloom area of the palm. These tests were designed to show whether the pollen band was accurately hitting the bloom area. The application gear selected is shown in Fig. 1. At flight speeds less than 40 mph the air flow from the rotor tended to blow the pollen to the ground rather than leaving it in the bloom area. At flight speeds greater than 50 mph the pilot could not maintain the proper height and centering between rows of palms, so the placement of pollen in the bloom area began to vary excessively.

Pollen Metering for the Helicopter.

The quantity of pollen applied during the first year's tests ranged from 2.4 to 14.4 in³/acre/application (7 to 42 in³/min, or 2.9 to 17.2 oz/min) as shown in Table 1. Pure pollen was metered from a hopper using two 5/8 inch diameter augers¹, timed 180° out of phase from each other to minimize pulsing of the delivery rate, running at speeds between 100 and 180 rpm. Flow of the pollen into the augers was not a problem because of its fine, free-flowing nature. It was found necessary to reduce the auger rpm observed in stationary calibration tests by about 10% to correct for the metering rate increase caused by vibration in flight. A pollen hopper, augers, and agitator shaft are shown in Fig. 2.

Pollen Distribution and Metering from a Fixed-Wing Aircraft. Arrangements

were made with Noel's Flying Service of Thermal, California, for test applications using a Model 235 Pawnee airplane equipped with a Model KE 3H1 Kintz dust spreader. Application tests were designed to repeat the experiments previously conducted by Preston and to compare the results of swath application by fixed-wing aircraft with band application by helicopter. A mixture of 12 parts bleached wheat flour plus one part of pollen was used so that the pollen could be accurately metered. Pollen placement tests, similar to those for the helicopter, were conducted before attempting actual pollination tests. The pollen mixture was spread at about 3 to 5 ft above the tips of the palm fronds, over 2 rows of palms on each pass, at a flight speed of 80 mph.

1966 POLLINATION TESTS

Plots of approximately one acre each were established at 12 ranches (Fig. 5). Aircraft applications were made every second day at half of these plots and every fourth day at the remaining plots, weather permitting. If the applications could not be made on the designated day, they were made as soon as possible thereafter. Data for both aircraft and hand

applications at each plot are given in Table 1. Pollen applied in these tests was blended to obtain an average viability of about 50%.

Eight coated glass slides were hung in the bloom area of 2 palms in one of each pair of plots just before pollen application and removed within one hour after the application.

At the completion of pollination a thinning experiment was conducted in each aircraft plot. All bunches on selected palms were either 1) not thinned, 2) center thinned or 3) normally thinned (i.e., thinned the same as hand-pollinated bunches).

When each plot was harvested, fruit set⁴, thinning, yield and grade results were obtained and compared to results in adjacent hand-pollinated plots.

Results. Average pollen deposits on the glass slides did not correspond to the

⁴Fruit set denotes the average distance between pollinated fruits on the strands of the bunches. It was calculated by dividing the total number of pollinated fruit on each palm into the total strand length of all the bunches on the palm.

TABLE 2. Summary of 1966 yield data

Plot code ¹	Aircraft application		Hand application				
	Fruit size ²	Unpollinated yield ³	Fruit size ²	Unpollinated yield ³	Pollinated yield ⁴	Bunches per palm ⁵	Strand length per palm ⁶
H - 1	48	17	58	0	238	16.0	9672
H - 2	45				336	16.5	13992
H - 3	45	16	51	0	251	17.5	7761
H - 4	45	23	56	0	365	17.5	12667
H - 5	51	3	55	1	203	14.5	11061
H - 6	46	18	58	0	298	16.5	10709
H - 7	41	11	53	0	363	17.0	13056
H - 8	46	7	55	0	389	16.0	12656
F - 9	49	14	54	0	248	15.5	11626
F - 10	42	32	42		176	14.0	7890
F - 11	46	16	53	0	316	16.0	11895
F - 12	45	15	56	0	247	15.5	8029

¹ H = Helicopter; F = Fixed-wing; numbers designate individual plot.

² Average number of pollinated fruit per pound for all thinning treatments at each plot.

³ Average percent of gross yield which was unpollinated for all thinning treatments at each plot.

⁴ Average pounds of pollinated fruit per palm.

⁵ Average number of bunches per palm.

⁶ Average inches of fruiting strand per palm, determined by multiplying the number of fruiting strands on each bunch by the fruiting length of each bunch and summing these products for all bunches on each palm.

TABLE 3. Summary of 1967 pollen application and yield data¹

Plot code ²	Aircraft pollination								Hand pollination	
	Pollen	Rate	Frequency	Number	Start	Finish	Fruit set ³	Pollinated yield	Fruit set	Pollinated yield
35	1	2.4	2	27	03/12	05/12	3.2	110	4	4
39	1	2.4	2	24	03/10	05/10	3.9	99	4	4
13	1½	3.6	2	21	03/17	05/05	2.0	135	4	4
33	1½	3.6	2	28	03/10	05/12	4.2	100	0.9	250
3	1	3.6	3	20	03/15	05/12	3.2	127	0.6	416
1	1	3.6	3	20	03/15	05/12	6.4	72	4	325

¹ All results are in the same terms as used in Tables 1 and 2 unless otherwise indicated.

² Ranch number assigned for 1967 tests and shown in Figure 6.

³ Inches of fruiting strand per pollinated fruit.

⁴ Data not available. Hand-pollinated-fruit-set-and-yield data were not taken in all plots but yields were satisfactory because paper bags were placed over all hand pollinated blooms.

³Each auger was made from a car-bit, a particular type of boring bit.

application rates of the helicopter method (Table 1). The average deposit often varied as much as 3 to 1 from one application to the next at each plot. Occasional variations between 5 to 1 and 10 to 1 were observed.

The fixed-wing applications resulted in about the same deposit at both plots checked, but this was less than the deposit by helicopter at the same rate of application. The lighter deposit was probably a result of fewer pollen grains in the bloom area because of swath application. Variation by the fixed-wing aircraft was somewhat greater than by the helicopter. Fixed-wing applications just after daybreak gave higher deposits than applications made later in the morning when temperatures were high enough to cause a slight thermal up-draft.

The fruit size in aircraft plots averaged about 45 fruit per lb. compared to 55 fruit per lb. for hand pollination (Table 2). Thus fruit in aircraft plots averaged 22% larger than hand-pollinated fruit. Averaging the door-grades (fruit as received at packing house) of all aircraft plots showed that the pollinated fruit averaged 61% marketable, 27% products and 12% culls. From 3 to 32% of the gross production of each aircraft plot was unpollinated fruit. Averaging the door-grades of all hand-pollinated plots showed that the pollinated fruit averaged 55% marketable, 33% products and 12% culls. No more than 1% of the gross production received at the packing house of each hand-pollinated plot was unpollinated fruit. Average results are presented here because door-grades for each thinning treatment in each plot were not obtained due to the greatly increased number of samples which the packinghouse would have been required to take. However, these results indicate that fruit in the aircraft plots was both larger and of slightly better quality than fruit in the hand-pollinated plots. On the other hand, substantially more unpollinated fruit developed in the aircraft plots than in the hand-pollinated plots.

The best fruit set in the aircraft plots resulted in those which had received 7.2 in³ of pollen per acre every second day by helicopter (Fig. 4). The plots which received 2.4 in³ of pollen per acre every second day had slightly lighter fruit set. Both plots which received 14.4 in³ of pollen per acre every fourth day frequently had wind during pollen application and were improperly thinned, so the results were not considered reliable. The fixed-wing plots were more variable than the helicopter plots and their average fruit set was not improved when applications were made every second day rather than every fourth day. Fruit set in the aircraft-pollinated plots was not equal to fruit set in the hand pollinated plots but was usually best in the part of the plot which was not thinned. A few bunches had poor fruit set even in the best plots.

The thinning treatments in each aircraft plot were compared by calculating the average total length of strand per bunch and dividing this value by the average strand length of hand-pollinated bunches. These results are shown as the percent of "normal thinned" (i.e., hand-pollinated bunch size) strand length (Fig. 4). Some of the normal and center thinned treatments were more severe than the thinning in the hand-pollinated part of the garden. The unthinned bun-



FIG. 1. Helicopter with gear developed for pollen application tests. Lightweight hoses, about 9 ft long, extend below the landing skids and are located 7.1 ft each side of the center line of the aircraft. Use of this gear, for the pollination tests, was FAA approved under the restricted category. The pollen metering rate shown is about 30 in³ acre for photographic purposes.

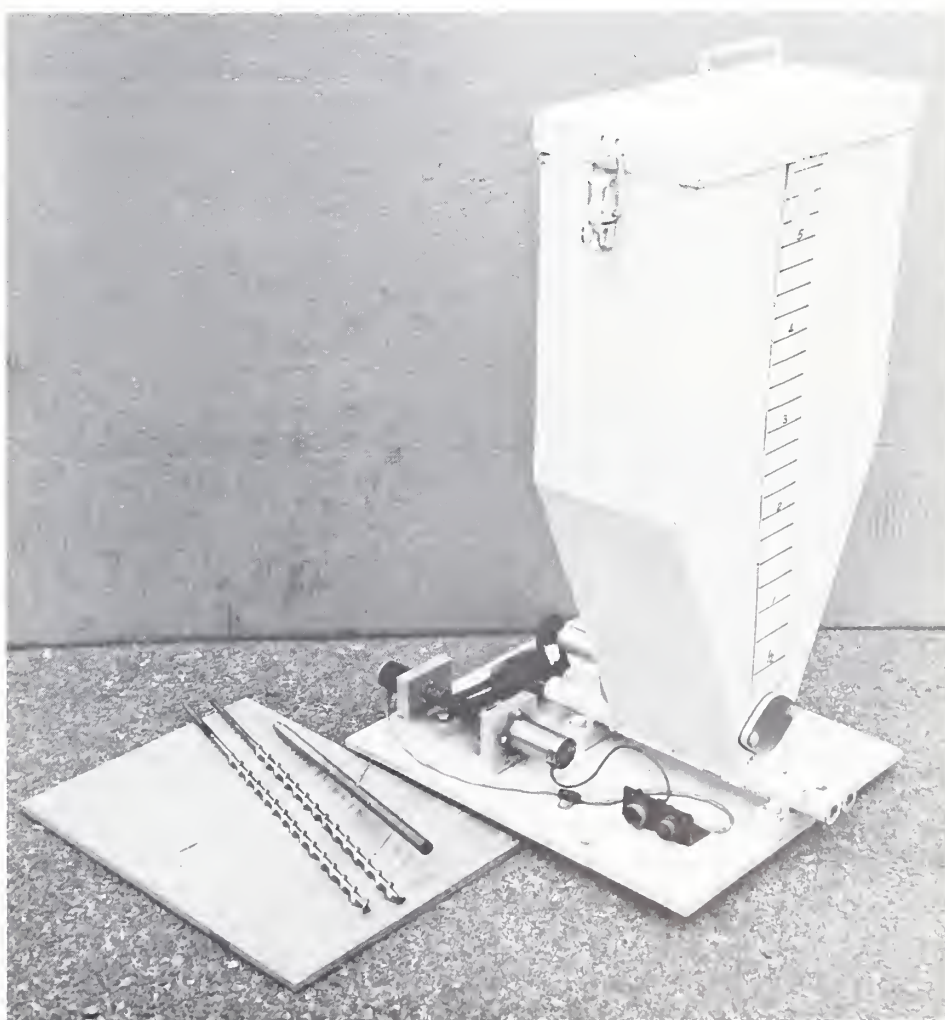


FIG. 2. Pollen hopper assembly, metering augers and agitator. Each hopper holds 1386 in³ of pollen.

ches were usually 50 to 100% larger than the bunches "normal thinned" and hand pollinated.

Theoretical yields were determined for each thinning treatment (Fig. 4) by calculating the average yield of pollinated fruit per bunch (lb.) of each thinning treatment and multiplying this value by the average number of bunches per palm in the hand-pollinated part of the date garden (Table 2). The unthinned part of most aircraft plots had the best yield, due to heavy fruit set on entire, large bunches, and equalled or exceeded hand pollination yields at a few plots.

1967 POLLINATION TESTS

The helicopter applications were continued and the fixed-wing applications ended. Since very little difference was apparent between the helicopter application of 2.4 in³ or 7.2 in³ of pollen per acre every second day, and the current supply of pollen was estimated to be less than would be required at the highest rate, the 1967 tests were conducted at lower application rates. Six plots of 10 acres each were paired for these tests (Table 3 and Fig. 5). Glass slide tests were not conducted this year although pollen placement was examined using 16mm cameras and visual observations. Each plot was marked so that the flight direction and pair of rows receiving pollen could be alternated at each application.

When each plot was harvested, fruit set, yield and grade results were obtained and compared to 1966 results as well as to 1967 hand pollination results.

Due to the shortage of workers for hand pollination several growers pooled about 400 acres and contracted with the helicopter operator to apply pollen to their acreage every second day at the rate of 3.6 in³ of pollen per acre. We determined fruit set and yield on some of this acreage (Fig. 5).

Results. All 6 plots had substantially poorer fruit set and yields than had been expected on the basis of the 1966 results. None of the bunches were thinned in any

of these plots. Plot 13 had the best average fruit set and fewer bunches with poor fruit set than any other plot.

The grower acreage varied from essentially no fruit set to about 3.8 inches of strand per pollinated fruit; consequently, yield varied from 0 to about 40% of hand-pollinated yield. Ranches at which pollen application was started before March 17 had good fruit set on the first blooms but not on those which opened later. Most ranches where application started about 7-10 days later did not have good fruit set on any bunches.

Packinghouse door-grades indicated that fruit size was similar to that observed in 1966. Ranches which were pollinated by aircraft and bagged at the khalal stage to protect the fruit averaged 70% marketable, 20% products and 10% culls for the pollinated yield only. The average door-grade for hand pollination at these ranches was 60% marketable, 20% products and 20% culls.

The 1967 tests were distributed over an area about 10 by 30 miles. The difference in fruit set between 1966 and 1967 appeared to be due to lower maximum temperatures during pollination in 1967, and the difference between plots and between grower acreage at various locations appeared to be due to temperature differences between locations. About 84% of the pollen applications in 1966 were made on days which reached a maximum temperature of 85°F or more, whereas about 78% of the applications in 1967 were made on days which reached a maximum of 85°F or less (Fig. 6). If temperature records had been obtained in each plot in 1966 and 1967, similar differences in temperature patterns between plots for the same year might have been evident.

RELATED STUDIES

A subsequent temperature and heat unit analysis (4) has shown that the daily maximum temperatures which occurred in 1966 were unusually warm and very favorable for good fruit set, whereas the period of peak bloom during 1967



FIG. 3. Fixed-wing aircraft used in 1966 pollen application tests. Delivery was calibrated using bleached wheat flour to insure proper application rates.

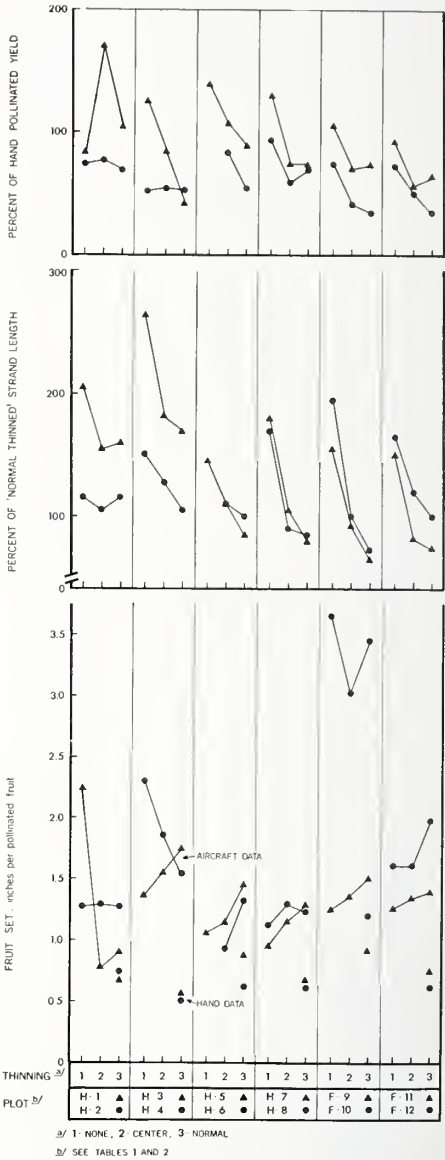


FIG. 4. Fruit set, thinning and yield data for plots pollinated by aircraft in 1966. Data points for all thinning treatments in each plot are connected by lines in order to show trends. Refer to Table 2 for additional comparisons and basic data obtained from hand pollinated plots.

was unusually cold and unfavorable for good fruit set. Also, temperature differences between the U. S. Weather Bureau Station at Indio and other date-producing locations within the Coachella Valley are relatively small but are sufficient to cause a wide spread in fruit-set results when daily temperatures are too low for good fruit set. A related study (13) has shown that the bloom area of date palms can average as much as 4°F cooler than a standard U. S. Weather Bureau shelter at 4½-feet above ground level.

The constant temperature-and-time relationship to pollen germination in a culture medium has recently been established for one variety of date pollen (5) and shows that constant temperatures of 40, 50, or 60°F substantially reduce both the rate and maximum level of germination compared to results at 72 or 80°F. Field tests have recently been completed in which constant temperatures of 60, 70, and 80°F have been maintained on date blooms following the application of pollen. It is hoped that such tests will eventually define the temperature conditions which favor fruit set. They may also provide a method for selecting pollen capable of germination and satisfactory fruit set under some of the conditions which presently result in unsatisfactory fruit set.

DISCUSSION

The 1966 results indicated that the helicopter method of pollen application would result in a higher and less variable pollen deposit than the fixed-wing method with equal rates of pollen application. The variation experienced with either method was presumably due to a combination of different flight, wind, and temperature conditions; pollen grains are very small and light, so their placement is easily affected by slight air movement. A uniform and adequate deposit of pollen on the blooms requires ideal conditions, which will not occur consistently when applications are made to substantial acreages.

Good hand pollination always requires thinning of the bloom to obtain good quality fruit. This thinning usually reduces the bloom to ½ - ¾ of its original size and number of fruit. Even though aircraft pollination methods resulted in less fruit set than hand pollination methods in 1966, it was possible to maintain yields, fruit size and quality by not thinning the bunches in aircraft plots. Thinning in the aircraft plots reduced both fruit set and yield. However, higher rates of pollen application would probably have resulted in better fruit set and necessitated some thinning.

The 1967 results indicate that the application rates of pollen selected for that year may have been too light for good results even in an average year. Grower records indicate that blooms which were hand pollinated and bagged had better fruit set than non-bagged blooms during the period of unfavorable temperatures (4). This suggests that higher rates of application in 1967 would not have resulted in fruit set and yields comparable to 1966 since bagging was more important in 1967 when temperatures were lower. However, higher rates should have given somewhat better results because, under the same conditions, the number of pollen grains able to germinate is directly proportional to the number of grains present. The viability of pollen

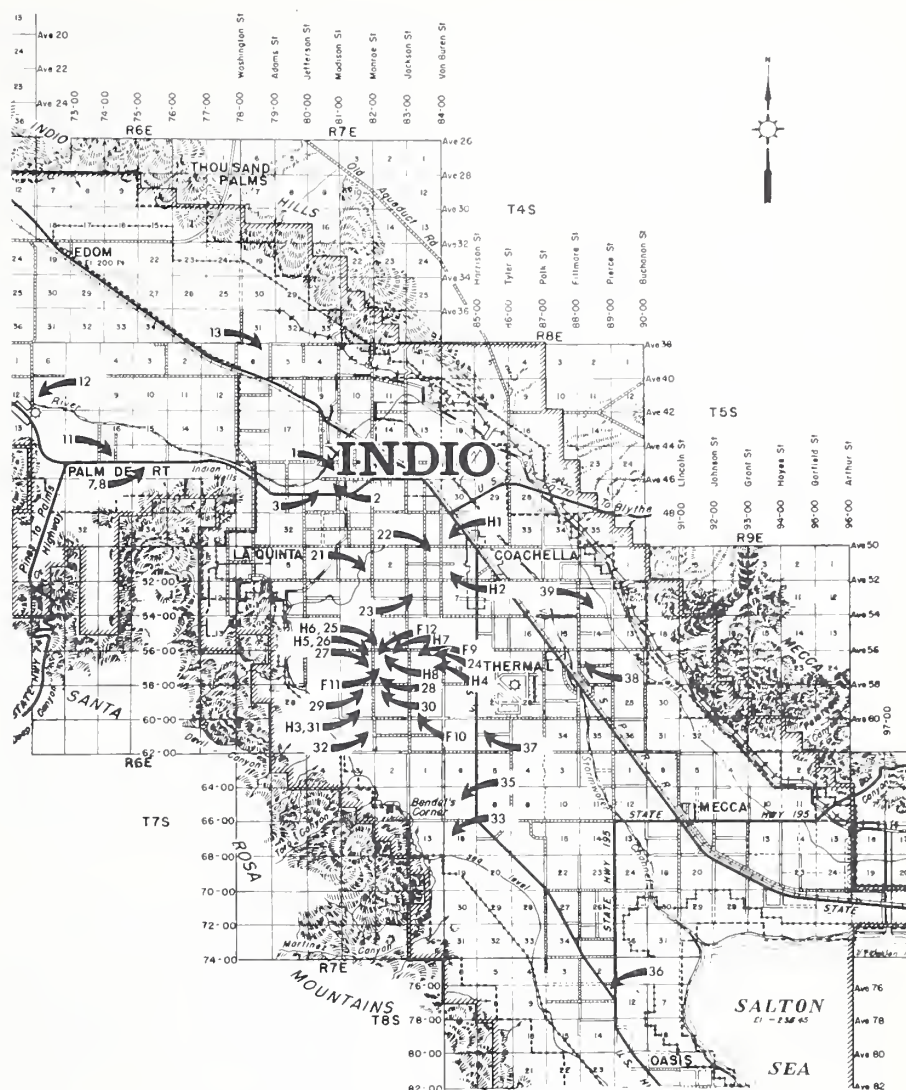


FIG. 5. Location of plots pollinated by aircraft in either 1966 or 1967. All 1967 plots and grower acreage pollinated entirely by aircraft are shown although data are given in Table 3 for only 6 experimental plots.

used in 1966 and 1967 was nearly the same.

The analysis of maximum temperatures and heat units which have occurred during the pollination season (4) indicates that weather conditions will be too unsettled for a mechanical pollination method to be used with confidence until nearly the end of March. Before this time the blooms should be hand pollinated and bagged (8) to assure good fruit set. After this time fruit set will still vary but should be good enough for mechanical pollination and appropriate adjustments in thinning to result in satisfactory yields.

Pollen application tests using aircraft were discontinued in 1968. Heavy pollen applications, rather than modification of the aircraft application equipment and techniques, appeared to be the only way to assure satisfactory fruit set and yield with aircraft application in most years. Additional planting of male palms, and at least 10 years, would be required to produce the estimated additional quantity of pollen needed. Mechanized methods of applying pollen from the ground were evaluated in 1968 (3) and 1969. The concentration of pollen in the bloom area of the palm has been increased without increasing the quantity of pollen

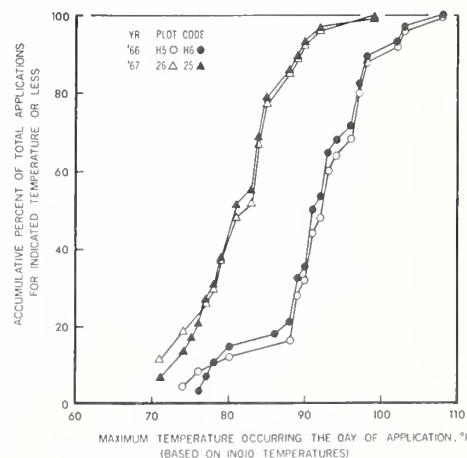


FIG. 6. Distribution of daily maximum temperatures recorded at Indio for two plots pollinated by helicopter in both 1966 and 1967.

required beyond 3 quarts (173 in³)/acre/season. Fruit set and yields in some 1968 plots were comparable to results from hand pollination. The cost of application is less than aircraft application and less than the present \$75-\$100 per acre for hand application.

Although large acreages may be covered quickly by aircraft pollination, many growers prefer to have personal control over the pollination of their acreages. If the supply of workers for pollination should be less than required to properly pollinate substantial acreages during peak bloom, the aircraft methods could be used with success if weather conditions were favorable.

Other date-producing areas of the world may be successful in applying pollen by aircraft if weather conditions are favorable. The oil palm plantations may also find these methods useful for supplemental pollination in order to achieve more uniform production. These findings may also be of interest to anyone considering supplemental pollination of other tree crops.

CONCLUSIONS

1. Metering and distribution equipment for a helicopter was developed which applied bands of pollen to date palms. The pollen bands then dispersed and continued to swirl in the tops of the palms as they were carried in the vortices of the rotor wake.

2. A swath of pollen applied to date palms from a fixed-wing crop duster did not result in so high a concentration of pollen in the bloom area of the palms. No attempt was made to develop band application equipment for the fixed-wing aircraft.

3. When temperatures and weather conditions were favorable for good fruit set, both the helicopter and fixed-wing methods of application resulted in less

fruit set, at the application rates used, than hand pollination methods. However, bunches pollinated by helicopter at the rate of 7.2 in³ of pollen per acre every second day and not thinned gave equal or greater yield than hand-pollinated and normally thinned bunches. When temperatures were unfavorable for good fruit set, the helicopter method resulted in substantially lower yields than hand pollination.

4. An analysis of temperature records for the Coachella Valley indicates that unfavorable weather will occur too frequently to recommend a change to aerial pollination methods for the entire season even if more pollen were available and applied. However in most years aerial pollination could begin in late March (4) if an adequate amount of pollen were available for application.

5. Aircraft methods could be used to pollinate large acreages if labor for hand pollination were unavailable and weather conditions were favorable.

6. Other areas of the world growing date palms or oil palms may benefit from these techniques if weather conditions are favorable.

Reference to a company or product name is for accuracy only and does not imply approval or disapproval by the U. S. Department of Agriculture or the California Agricultural Experiment Station.

LITERATURE CITED

1. Alexander, D. B. W. 1952. A method of pollinating dates. *Date Growers' Inst. Rep.* 29:20.
2. Bell Helicopter Co. 1964. New techniques in helicopter aerial application. (Mimeographed, illustrated booklet.)

3. Brown, G. K., R. M. Perkins, and E. G. Vis. 1969. Developing ground-level equipment for pollinating dates. *Date Growers' Inst. Rep.* 46:_____.
4. _____, _____, and _____. 1969. Temperature and heat unit occurrences during date pollination in the Coachella Valley of California. *Date Growers' Inst. Rep.* 46:_____.
5. Furr, J. R., and C. L. Ream. 1968. The influence of temperature on germination of date pollen. *Date Growers' Inst. Rep.* 45: 7-9.
6. Gray, B. S. 1969. The requirement for assisted pollination in oil palms in Malaysia, p 46-66. In *Progress in oil palm*. Inc. Soc. Planters. Kuala Lumpur.
7. Hardon, J. J., and P. D. Turner. 1966. Observations on natural pollination in commercial palms of oil palm (*Elaeis Guineensis*). *Exp. Agr.* 3: 105-116.
8. Nixon, R. W. 1966. Growing dates in the United States. U.S. Dep. Agr. *Info. Bull.* 207. 56 p.
9. Preston, R. D. 1964. Pollinating dates by airplane. *Date Growers' Inst. Rep.* 41: 24.
10. _____. 1966. Pollination of dates by fixed-wing aircraft. *Date Growers' Inst. Rep.* 43: 28.
11. Swingle, L., W. E. Geissler, R. D. Preston, and T. Codekas. 1965. Panel discussion of labor-saving devices in pollinating dates. *Date Growers' Inst. Rep.* 42: 6-7.
12. Veldhuis, J. 1968. Methods of assisted pollination for oil palms, p 72-82. In *Oil palm developments in Malaysia*. Inc. Soc. Planters. Kuala Lumpur.
13. Vis, E. G., G. K. Brown, and R. M. Perkins. 1969. The effect of elevation and time on air temperature during date pollination. *Date Growers' Inst. Rep.* 46:_____.

MEMBERSHIP ROLL 1969-1970*

SUSTAINING MEMBERS

Brown, T. R., Route 2, Box 81.....Thermal
Cavanagh, H. L., 76-353 Highway 111...Palm Desert
Date Administrative Committee, Box 764.....Indio
Furr, J. R., U.S. Date and Citrus Station,
44-455 Clinton St.....Indio
Remy, Henri, Apartado Postal 22,
Saltillo, Coahuila, Mexico
Royal Medjool Date Ranch, Box 551.....Yuma, Ariz.
Shields Date Gardens, 80-225 Hwy 111.....Indio
Swingle, Leonhardt, 44-566 Swingle Ave.....Indio
Weinert, A. H., Smoke Tree Ranch.....Palm Springs
Yowell, Hillman, 43-900 Oasis Ave.....Indio

REGULAR MEMBERS

Allen, Sarah M., Box 1416.....Indio
Azhderian, Leo., 6864 W. Clinton.....Fresno
Baker, Donald F. and Rowena,
319 E. Randolph St.....Glendale
Benjamin, Namrod, Dept. Food Science and
Technology, Oregon State Univ.....Corvallis, Ore.
Berryman, Harley, P.O. Box 882.....Bard
Blackburn, R. W and Sons,
Route 2, Box 266.....Thermal
Buxton, Steve, Route 1, Box 214.....Thermal
Carpenter, John, U.S. Date and Citrus Station,
44-455 Clinton.....Indio
Carreon, Dr. R. J., Jr., Box CC.....Indio
Christian, E. L. (Sunipalms Date Gardens)
Box 252.....Indio
Clark, William J., 37-165 Palm View Rd.
Cathedral City
C.M.B.G. Ranch (J. C. Pixton)
P.O. Drawer YY.....Indio
Coachella Ranches (D. A. Stevning),
51-064 Monroe St.....Indio
Coachella Valley Fruit Co., Box 833.....Indio
Codekas Bros., P.O. Drawer E.....Indio
College of the Desert, 43-500 Monterey Ave.,
Palm Desert
Diemer & Oberlin, R.R. 1.....Pontiac, Ill.
Dixon, W. L. Co. (Pete Dondero),
81-931 Victoria St.....Indio
Dunlap, D. D., Box 322.....Thermal
Eastslope Ranch, 75-475 Desert Park Dr.,
Palm Desert
Elmer, Harold S., 12 Entomology,
University of California.....Riverside
El Mima Date Garden (V. de Fontenay),
P.O. Box 170.....Alice Springs, Australia
Embleton, Tom W., 209 Horticulture Bldg.,
University of California.....Riverside
Ensley, Harold E., P.O. Drawer 1787.....Indio
F & R Ranch (Ranney Enterprises),
12550 Brookhurst, Suite J.....Garden Grove
Fairfield Farms, P.O. Box 564.....La Quinta
Fowler, Bob, 1028 Adams.....El Centro
Fruit & Food Tech., Research Institute, Chief
Private Bag.....Stellanbosch, South Africa
Gibbs, Gordon E., c/o A. L. Cooke,
Box 955.....Coachella
Hilgeman, Robert, University of Arizona,
Citrus Branch Station.....Tempe, Ariz.
Hopland, A. N., 49-773 Monroe.....Indio
Howie, Robert M., Riverside County Agric.
Commissioner, 4080 Lemon St.....Riverside
Hughes, Larry, 11421 Chenault St.....Los Angeles
Jamison, Homer B., Rt. 1, Box 101.....Coachella
Jones, O. A. (Art), 1680 Ford St.....Redlands

Keck, Albert P. Company, P.O. Drawer FF.....Indio
Laflin, Ben, Sr., Box 757.....Thermal
Laflin, Ben, Jr., Box 757.....Thermal
Lauderbach, Leon W., 1451 Bryan Ave.....Tustin
Leslie Ranch Nurseries, 81-502 Avenue 50.....Indio
Lesser, Dr. Joseph H., c/o 1701 N. Palm Canyon Dr.,
Palm Springs
Lindgren, David L., University of California,
Citrus Research Center.....Riverside
Livingston, Walter, 1310 Wilshire Blvd., Los Angeles
Lluvia De Oro Ranch (Irl H. Buxton),
4056 Williams Ave.....La Verne
Loud, A. R., P.O. Box 2039.....Pomona
Marx, Donald, P.O. Box 1478.....Palm Springs
McLain, V. C., Estate, 1420 Seventh St.....Wasco
McLeod, Rose L., 622 Main St.....Lewiston, Idaho
Morris, Arden S. and H. R.,
4200 Bereford Way.....Pasadena
Muhs, Arthur B., Box Y.....Palm Springs
Nelsen, Helen, 24860 Calabasas Road.....Calabasas
Nicoll, R. C. (Valerie Jean Date Shop),
66021 Hwy 86.....Thermal
Nixon, Roy W., 81-229 Palmyra Ave.....Indio
Odium, Bruce W., Box 787.....Indio
Odium, Floyd B., P.O. Box FFF.....Indio
Olivieri, Pat, c/o H & O Ranch,
970 Sierra Way.....Palm Springs
Patterson, K. K., 81-370 Date Palm Ave.....Indio
Philbrick, Dr. R. E., 6695 Magnolia Ave.....Riverside
Pierson, Rollins, 7845 Torreyson Dr.....Los Angeles
Preston, Richard D.,
17656 Santa Teresa Circle.....Fountain Valley
Rancho Ramona, Inc., 81-855 Hwy 111,
Room 2-J.....Indio
Rapkin, Joseph, 735 N. Water St.....Milwaukee, Wisc.
Reuther, Walter, Dept. of Hort. Science,
University of California.....Riverside
Richardson, H. B., Hort. Science Bldg.,
University of California.....Davis
Robinson, Donald, U.S. Department
of Agriculture, 45-235 Towne.....Indio
Rogers, David A., Route 1, Box 271.....Winterhaven
Rummonds, Raymond, Route 1, Box 181 R.....Indio
Rutherford, Paul, Route 1, Box 73.....Coachella
Rygg, G. L., Box 700.....Pomona
Schmid, Thomas, Route 1, Box 35.....Coachella
Schmid, Walter, 7931 Lampson Ave.....Garden Grove
Shearer, S. K., M. D. Et al,
511 Toyopa Dr.....Pacific Palisades
Siemen, Evelyn M., Box 44.....Palm Desert
Skar Ship Corp., 21 West St.....New York, N.Y.
Smigel, George E. Corp., 2017 Granville, Los Angeles
Snow, Dr. Rodney H., 301 - 20th St.....Santa Monica
Solero Ranch (W. Murphy), P.O. Box 622.....San Jose
Strehle, Hazel M., 355 West 8th St.....Eugene, Ore.
Swingle, Mrs. Walter T., 3400 Laguna St.,
#309.....San Francisco
Thielemeir, Lawrence G., Box 265.....Santa Ana
Universidad De Sonora, Escuela de Agricultura,
Apartado 305.....Hermosillo, Sonora, Mexico
U.S. Date & Citrus Station, 44-455 Clinton St. Indio
Ward, Edith E. (Dorado Enterprises),
73-661 Highway 111.....Palm Desert
Waters Estates, c/o Sec. Pacific Natl Bank,
707 N. Palm Canyon.....Palm Springs
Webb, Robert W., Jr.,
8 Warm Sands Pl.....Palm Springs
Willits & Newcomb, Inc., Route 2, Box 72.....Thermal
Wilson, Gwynn, 75-075 Hwy 111.....Palm Desert
Winder, Gary, P.O. Box 733.....Bard
Yost, Leland J., Route 2, Box 124.....Thermal
Young, Dr. Forrest O., c/o Harboe Management,
P.O. Drawer 1787.....Indio

* All addresses California unless otherwise specified.

NATIONAL AGRICULTURAL LIBRARY



1022934322